MINING PROJECT EVALUATION PROCESS FOR INVESTMENT DECISIONS

by

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STATEMENT OF THESIS APPROVAL

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ABSTRACT

Mining and the related industries play an important role in the Korean economy. The Korean mining industry is relatively small. There are several mines in Korea but they are very small, and production is low in comparison with other countries' mines.
Thus Korea must take part in mineral projects all over the world to secure essential minerals such as coal, copper, uranium, iron ore, zinc, and nickel to support its manufacturing industries. For that reason, the Korean government established K Company[1] as a government corporation to invest in mineral deposits throughout the world. However there are several major entities, including BHP Billiton, Rio Tinto, Anglo American, Xstrata, Freeport McMoRan, Chinese government-run companies, and Japanese trading companies that have large foreign holdings, controlling deposits in most of the world's established and productive mining districts. As a relative newcomer, K Company is having difficulty breaking into these markets.

In general, the mining industry considers the United States, Canada, Australia, and European countries to have good mining investment environments, but because the major companies have already achieved market dominance in those countries large investments are required. Thus K Company is increasingly turning to new areas like South America (Peru and Bolivia) and Africa. The competition among businesses to secure a share of the

[1] To preserve its anonymity, the company established by the Korean government is referred to throughout this thesis as "K Company." For the same reason, the projects and investments of K Company discussed herein are referred to only by initials.

new market is intense but there are still good investment opportunities. However, because most of the countries in these areas are not well developed, there are several additional risks associated with participation in mining projects there.

Risk is a major factor in all mining activities, arising from many internal and external variables. In this thesis, those variables are identified, and their effects evaluated, based on a survey of 31 experts. A statistical model to analyze the effect of risk on the economic feasibility of mine development and operation at a given location is presented, and validated using analysis from projects at K Company. The guidelines and model, as presented here, will enable K Company and other investors to make better investment decisions in the future.

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CHAPTER 1

INTRODUCTION

Korea is the ninth largest energy consumer, the fifth largest petroleum importer, and the second largest coal importer in the world. Korea imports 97% of the energy and mineral resources it uses, at an annual cost of $85 billion. Independent resource developments are one of the key tasks for Korea's economic development.

Consider two commodities, coal and copper. Korea imports most of its bituminous coal from Australia, Indonesia, Canada, and Russia, with Australia and Indonesia supplying 80% of that amount. Korea has a large copper smelter, operated by LS-Nikko, but no copper mines. Therefore, the smelter is fully supplied by concentrates imported from Australia, Chile, Indonesia, and Papua New Guinea. Thus it is clear that Korea needs better diversification of sources for imported mineral commodities, but it is not easy to accomplish that.

K Company is a wholly-owned government entity, focusing on securing stable supplies of mineral resources for Korean industries. Its main purpose is securing stable supply of overseas mineral resources for Korean industry, but it also works to aid in rational development of domestic mines. K Company is especially focusing on securing supplies of the six minerals designated as strategic by the Korean government, namely coal, uranium, iron ore, copper, zinc, and nickel.

K Company engages in mineral resource development, mineral information service, and mineral research activities in Korea. The company focuses on supplying energy and industrial mineral resources, as described above. Its services include surveys of investment conditions and circumstances for Korean consumers of mineral commodities. In 1994, K Company started a business in which it invests directly in mineral deposits outside Korea. As of 2011, it has invested in 35 projects in 15 countries. Table 1.1 gives an overview of the company's strategically important coal and copper projects.

TABLE 1.1 Overview of K Company's coal and copper projects

Name	Location	Resource	Grade	Production	Year	Investment Amounts
1	Australia	72 Mt	Bituminous	3.3 Mt/yr	2000	$20 million
2	Australia	30 Mt	Bituminous	3 Mt/yr	2006	$53 million
3	Australia	34 Mt	Bituminous	2.5 Mt/yr	2006	$8 million
4	Australia	438 Mt	Bituminous	6 Mt/yr	2009	$143 million
5	Australia	325 Mt	Bituminous	16 Mt/yr	2008	$83 million
6	South Africa	75 Mt	Bituminous	3 Mt/yr	2010	$16 million
7	Australia	1,380 Mt	Bituminous	4.5 Mt/yr	1995	$40 million
8	Australia	280 Mt	Bituminous	2.6 Mt/yr	1994	$7 million
9	Australia	510 Mt	Bituminous	2.5 Mt/yr	2008	$78 million
10	Australia	560 Mt	Bituminous	3 Mt/yr	2006	$1.6 million
11	Australia	100 Mt	Bituminous	2 Mt/yr	2006	$0.4 million
12	Philippine	3 Mt	25% Copper	24 ktpy	2003	$58 million
13	China	1.4 Mt	0.67% Copper	100 ktpy	2007	$226 million
14	Mexico	75 Mt	0.93% Copper	60 ktpy	2008	$119 million
15	Canada	12 Mt	0.35% Copper	3.7 ktpy	2005	$2.4 million
16	Peru	402 Mt	0.77% Copper	60 ktpy	2004	$32 million
17	Peru	-	-	-	2008	-
18	Mongolia	74 Mt	0.32% Copper	30 ktpy	2006	-
19	Bolivia	-	-	-	2008	-
20	Panama	1,642 Mt	0.47% Copper	230 ktpy	2009	$18 million
21	United States	560 Mt	0.45% Copper	28 ktpy	2010	$42 million
22	Canada	7.2 Mt	1.73% Copper	33 ktpy	2011	$175 million
23	Chile	486 Mt	0.32% Copper	50 ktpy	2011	$194 million

Source : K Company's internal information in possession of author

Figure 1.1 shows K Company's existing 23 projects in Eurasia, Oceania, and Africa. Blue indicates operating/producing projects, yellow exploration projects, and green developing projects. Note that the largest group is coal projects in Australia.

Korea is the world's second largest importer of thermal coal after Japan, historically accounting for around 10 to 11% of the global imports. Seaborne thermal coal demand Korea accounted for approximately 12% of Korea's imports in 2010 and is expected to remain around 12% for 2011 and 2012.

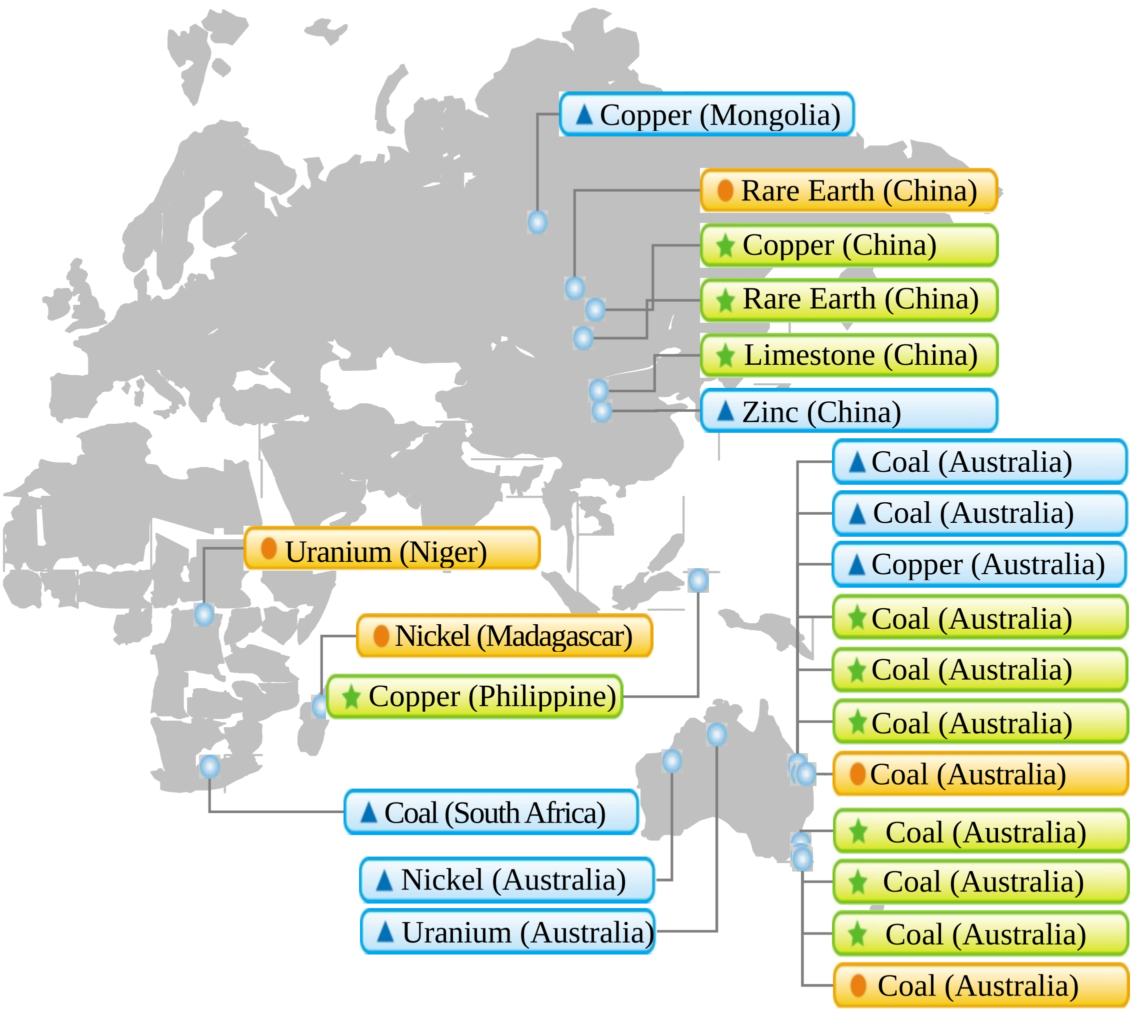


FIGURE 1.1 Projects located in Eurasia, Oceania, and Africa

The growth of thermal coal consumption in recent years has been driven mainly by the replacement of oil-fired electricity generation capacity by coal-fired generators, fuelled by a combination of domestically produced anthracite and imported steam coal. South Korea has limited reserves of coal, mainly anthracite. Anthracite production in Korea is limited by the amount of available reserves and the cost of production. Korea's anthracite producing industry is heavily subsidized by the government, as otherwise domestic mining costs would be two to four times higher than in major exporting countries. Despite these subsidies South Korea continues to import around 98% of its thermal coal requirements, a proportion that is expected to reach 100% in the future.

Korea imports all of its bituminous steam coal from overseas, with 71% coming from Australia and Indonesia. Australia provided an estimated 35% of imports in 2011, and will increase its share slightly in the next decade as large scale thermal coal projects and their corresponding infrastructure developments come online. During the same time period, Indonesia is expected to provide an estimated 36% of the Korean demand of thermal coal (KITA 2011). Many Korean firms have entered countries such as Australia, Indonesia, China, and Canada to promote coal-development projects, but none have yet entered into other areas which have abundant coal resources such as Russia, eastern African, and Mongolia.

Figure 1.2 shows K Company's 12 existing projects which are located on the American continent. Blue indicates operating/producing projects, yellow indicates exploration projects, and green indicates developing projects. Most projects are related to copper.

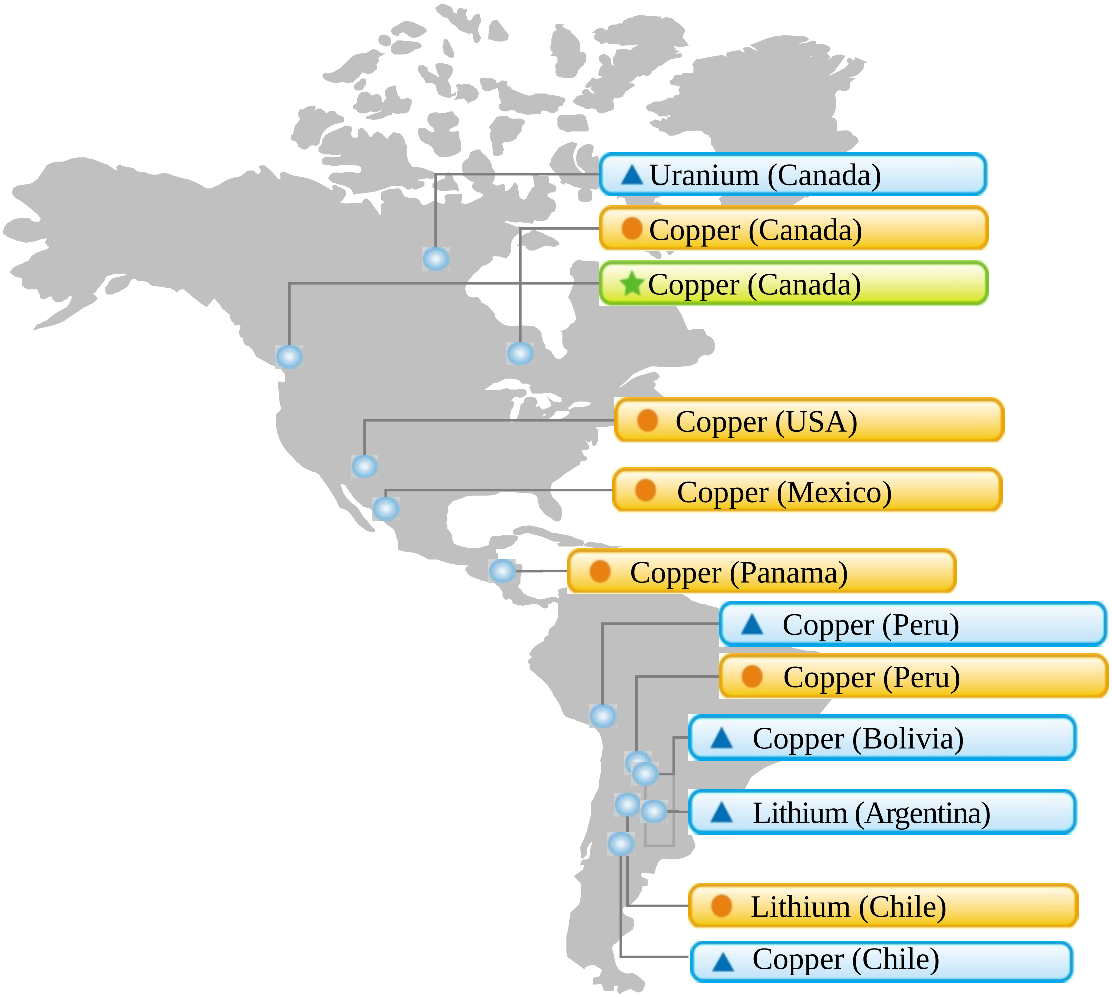
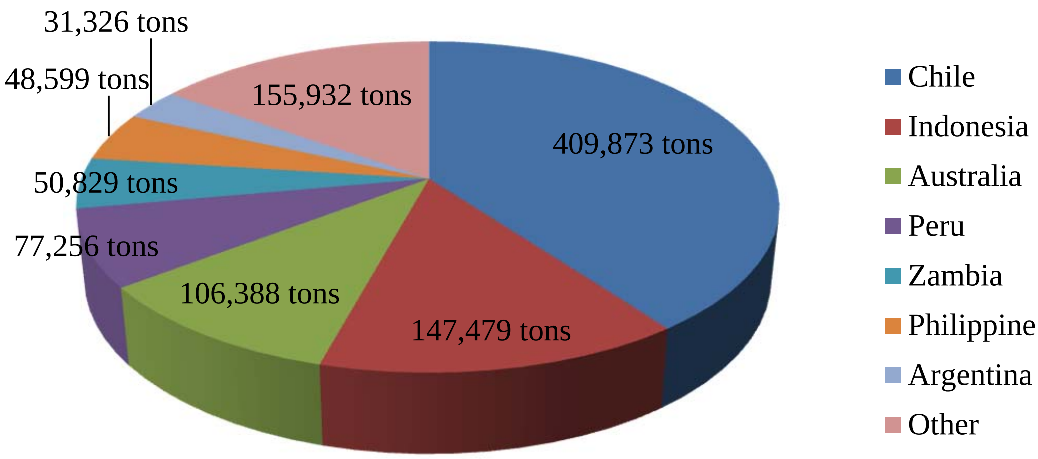


FIGURE 1.2 Projects located in North and South America

Because of its limited indigenous mineral resources, the Republic of Korea relies almost 100% on imports to meet its requirements for ores and concentrates of copper, which amounted to about 1.7Mt in 2010 (Figure 1.3).

To meet the domestic refined copper requirements, the country also imported about 428,000 tons of refined copper from Chile, Indonesia, Australia, Peru, Zambia, the Philippines, and Argentina.



Source: KITA 2011

FIGURE 1.3 Demand for refined copper by Korea in 2010

If Korea wants to become an advanced economy, it must do more than sell its manufactured goods in rich countries. It must also do more business in regions previously neglected such as Africa, South America, and Southeast Asia. As a relative new investor in mineral projects, K Company is having difficulty breaking into stable markets like Australia, Canada, and the United States. Even when there are opportunities, it is difficult to finalize purchase agreements because of extremely high premiums, relatively poor working conditions and low quality products. Thus there are compelling reasons to invest in mineral projects in developing countries. Furthermore, based on the author's experience, Korea has a good image in developing countries, many of which see Korea as a role model for rapid economic development. These countries often empathize with Korea, knowing that it too suffered from hunger, a civil war, and colonialism, and they know that Korea is not imperialistic.

Finally, conditions in many developing countries can make development of mining projects difficult. There are political and social risks, commodity risks, and to a lesser extent, technical and environmental risks.

In summary Korea has an ongoing need for sources of mineral commodities from outside its own borders, but has historically had difficulty developed those sources in countries where the mining industry is well established. Developing countries offer a good opportunity for Korean investment in mining projects, and Korea has a good reputation among most of those countries. However, the risks associated with mineral investments must be carefully considered.

CHAPTER 2

BACKGROUND

The process of mining project evaluation is long and complex. The use of standardized, systematic methods allows an investor to properly rank investment alternatives according to selected criteria so that better and more consistent decisions can be made. This chapter discusses several topics that are important to understanding the model for investment risk analysis that was developed as the outcome of this research. Those topics include the mineral industry of the Republic of Korea, mineral project analysis, mineral project valuation analysis with selection criteria, current coal and copper mining methods and constraints, and mining project risk analysis.

2.1 The Mineral Industry of the Republic of Korea

The Republic of Korea has limited resources of the minerals to support the country’s consumption and robust manufacturing sector, such as coal, gold, iron ore, lead, silver, antimony, molybdenum, tin, tungsten, zinc, and offshore natural gas. The mining sector is one of the smallest sectors of the Republic of Korea’s economy. The output of the mining and quarrying sector accounted for only 0.21% of the country’s Gross Domestic Product (GDP) in 2008 (BOK 2009). The Republic of Korea’s mining sector mines ores to produce metals and nonmetal products. Though the domestic mine output of ferrous and nonferrous metals is small compared with the raw material that was required by the refining industries, the metals and metal products produced in the country play an essential role in satisfying domestic demand for industrial materials and in trade. Nonmetal minerals and mineral products are usually used by domestic industries. Small amounts of anthracite coal are also produced.

The country’s large coal mining, petroleum, natural gas, petrochemical, and petroleum refining companies are state-owned and under the superintendence of the Ministry of Knowledge Economy (MKE). The rest of the mining, quarrying, and ferrous and nonferrous metal processing companies are privately owned and operated.

The Republic of Korea consumes resources imported from both developing and developed countries, and directed efforts to secure those resources began with the two oil crises that occurred in the 1970s. The acceleration of the development of overseas resources arose from the notion that Korea, which relies on imports of principal energy and necessary minerals and needs lots of resources, must secure these resources to insure future national economic growth.

The Korean government established the main plan for overseas resource development and selected the most important strategic minerals based on the scale of their import and their significance to the domestic industries in 2001. The strategic minerals include petroleum, natural gas, bituminous coal, uranium, iron ore, copper, zinc, and nickel. Based on actual records of supply and demand, these minerals were grouped into two categories, the petroleum and natural gas group and the bituminous coal and mineral resources group. These two groups were assigned their respective targets for self-reliant development as well as priority tasks for reaching those targets. In 1990, the

Korean government established a policy of managing overseas resources projects more actively to secure the energy and industrial minerals, which are mostly imported from the other countries. This was done because of the increasing uncertainty of international resources markets.

As shown in Table 2.1, through 2010 Korea has invested $8.53 billion in 419 projects for minerals besides petroleum and natural gas. Of these, 143 projects are in the exploration phase, and 146 are in the development or production phase, and 130 have been terminated. Projects in their exploration, development, or production phases are classified according to mineral type with the following breakdown: Seventy-six bituminous coal projects are currently being pursued, with 31 projects in the exploration phase, 13 in the development phase, and 32 in the production phase. Thirty copper projects are in the exploration phase, eight are under development, and four are in production.

TABLE 2.1 Overseas resources development project status

	Projects in progress				Terminated	Total
	Exploration	Development	Production	Total		
Number of businesses	143	90	56	289	130	419
Investment amounts ($ million)	966	1,790	5,089	7,845	687	8,532
Mineral Commodities	22	26	15	35	19	37
Countries	33	28	15	46	38	58
Companies	155	105	53	280	98	356

Source : K Company's internal information in possession of author

2.2 Mineral Project Analysis

The evaluation of a mining project from exploration to exploitation is a complicated process. Evaluation activities for a project are begun when a deposit is discovered and continued through to start of construction. The technical feasibility and the economic viability of each project are analyzed and refined during the phases of mine development, with more detailed engineering data required at each stage. Three levels of engineering studies during development are commonly used by the mining industry: the conceptual study, the preliminary feasibility study, and the feasibility study (Bullock 2011).

2.2.1 Conceptual Study

The conceptual study, sometimes referred to as a scoping study, is the initial level study and the preliminary evaluation of mining projects. The principal parameters for a conceptual study are mostly assumed and factored. Accordingly, the level of inaccuracy is taken as ±50%. Though a conceptual study is useful as a tool, and important in deciding if subsequent engineering studies are warranted, it is neither valid for economic decision making nor sufficient for reserve reporting (Nelson 2011).

2.2.2 Preliminary Feasibility Study

The preliminary feasibility study represents an intermediate step in the engineering process of evaluating a mining project. The principal parameters for a pre-feasibility study are based on a well-defined engineering basis. The level of accuracy is higher than in the scoping study, at ±25%. The economic analysis of a preliminary feasibility study is of sufficient accuracy to assess various development options and overall project viability. However, these cost estimates and engineering parameters are typically not considered of sufficient accuracy for final decision making or financing. The study may or may not be sufficient for reserve reporting. Without a preliminary feasibility study, the more costly and time consuming final feasibility study may focus on a less optimum mine design or process plan (Nelson 2011).

2.2.3 Feasibility Study

A feasibility study describes the last and most detailed step in the engineering process for evaluating a mining project, usually leading to “go or no-go” decision and financing plan. Principal parameters for a feasibility study are based on complete engineering analysis. The level of accuracy is higher than the preliminary feasibility study, usually ±15%. Often the term “bankable” is used in describing a feasibility study. This term implies that the level of detail of the study is sufficient to justify a decision for funding, provided the results are positive (Nelson 2011).

2.3 Mineral Project Valuation Analysis and Selection Criteria

Any company has managerial and financial resources and a choice has to be made among alternatives based on some tangible measurement of economic value or return, along with other criteria. The three major methods for quantifying economic value, discussed below, are all based on the annual cash flows for the project.

2.3.1 The Time Value of Money

Final economic analysis is based on annual cash flow calculations for the entire mine life. Economic analysis is performed as the final step in a study to provide a measure of the project's economic viability. Economic evaluation indicators generally include the net present value (NPV) at selected discount rates, and the internal rate of return (IRR). In feasibility studies, technical, economic and financial factors are carefully considered and analyzed. These studies are made on the basis of limited, often purely subjective, information. Uncertainties are associated therefore with both the input estimates and corresponding economic evaluation indicators such as NPV and IRR. When the NPV method is used, the first criterion for project evaluation is the NPV itself. It must of course be positive, and usually must be above a certain, minimum value determined by the company's internal standards. If the NPV is positive, three other key criteria are necessarily satisfied:

- The initial capital investment is recovered;
- The financial return on the mining investment is greater than the particular interest rate;
- The net present value which is usually called the acquisition value or premium of the mineralization concerned.

The selection of an appropriate interest rate is critical in the application of NPV as a valuation and ranking technique, as this discounts the cash flow and determines the net present value (Scott and Whateley 2006).

The IRR (Internal Rate of Return) method is a special case of the NPV method, where the interest rate chosen is that which will exactly discount the future cash flows of a project to a present value equal to the initial capital investment, so the NPV is zero.

Cash flows are tested by sensitivity analysis in the valuation and ranking of mineralization, mineral properties, and projects before mining companies proceed to developing a mine. A minimum acceptance rate of return (the hurdle rate) is usually stated, below which projects are not considered. Some analyses consider inflation, but of course future inflation rates must be estimated and accurate estimates are difficult. Detailed analyses may also include a probabilistic analysis of various risk factors. These methods are described in detail in Chapter 4.

2.3.2 Payback Period

The payback period (PBP) is the time required for a project to generate cash flow or profits equal to the initial capital investment. Calculation of the payback period is a basic method that ranks mineral projects in order of their value by the time required to recover the initial capital investment from the project cash flow.

2.3.3 Operating Margin to Initial Investment Ratio

The ratio of operating margin to initial investment is easy to calculate. In contrast with the PBP method, which only looks at the early portion of the project, this method considers the project’s entire life. All of the elements in the cash flow such as revenue, capital costs, operating cost, taxes, etc. are taken into consideration and all affect the ratio. However, as in payback period, the time value of money is taken into consideration (Scott and Whateley 2006).

2.4 Mineral Commodities Considered

For purposes of analysis and model calibration, this thesis considers investments in two mineral commodities, coal and copper. The following discussion provides basic information on the production of those two commodities.

2.4.1 Coal Production

Coal is a combustible, carbonaceous, sedimentary rock, formed from peat. Coal seams vary greatly in thickness, from millimeters to many meters in thickness. A stratigraphic unit comprising layered sedimentary rocks interspersed with coal seams is described as a coal measure. Coal varies in color from light brown to black, is dull to brilliant in luster, has relatively low hardness and a low specific gravity, and is non-crystalline and brittle.

A coal unit can be classified in terms of the level of geologic maturity achieved. A series of stages, characterized by a set of readily observable properties, has been established and widely accepted. The rank system begins with peat (the first step in the formation of coal), followed by lignite, sub-bituminous, bituminous, semi-anthracite, anthracite and graphite.

In 2010, the World Energy Council estimated total global coal reserves to be 860 billion tons, with bituminous including anthracite coal reserves at 405 billion tons, and sub-bituminous and lignite coal reserves at 455 billion tons. Coal deposits, both economic and uneconomic, are widely spread throughout the world. Economically recoverable reserves of coal are found in more than 70 countries. However, the bulk of identified coal reserves are found in just a few countries, with the United States, Russia, and China accounting for 60% of proven coal reserves.

The surface or open cut mining of coal on a large scale is a relatively recent development in the world coal industry. For many years, the high cost of removing huge volumes of overburden (wastes) was the main reason for the restricted use of open cut coal mining. However, the development of large equipment such as shovels and draglines made surface mining attractive. Surface mining has major advantages over underground mining in safety and in the much higher recovery of the coal resource because there is no need to leave pillars. Surface mining also has the ability to recover the whole extent of thick seams.

Most surface mines follow the same basic steps to produce coal. First, bulldozers clear trees and other large objects. The topsoil is then removed from the area to be mined and stockpiled for later use in rehabilitation. The weathered material under the topsoil is often removed in a prestrip operation, and then the competent overburden is blasted, prior to removal using the main overburden stripping equipment. A wide range of earthmoving equipment such as shovels, front-end loaders, draglines, bucket wheels, etc., is used in removing the broken overburden in order to expose the coal. After the overburden is removed, the exposed coal is loaded and hauled to locations where it may be further processed or used directly. Surface excavations are then backfilled, recontoured, and revegetated as required by applicable regulations and expectations.

Underground mining of coal has been practiced for hundreds of years, starting first with the breaking and loading of the coal using simple hand tools, and extending today to complex, mechanized systems. The appearance of the continuous miner after World War II, coupled with the use of conveyor belts, led to a substantial increase in coal production by underground methods. More recently, coal extraction by longwall methods has accounted for an increasing proportion of underground production.

Often the quality of raw coal recovered from a mine is not suited to the customer's requirements, owing to contamination with incombustible material (called ash) or sulfur-bearing pyrite. The purpose of coal preparation to convert run-of-mine coal into a saleable product at a final cost acceptable to all parties. Coal preparation commonly reduces ash and sulfur content, controls size and moisture content, and ensures consistency within grades. The technologies of processes that utilize coal are becoming increasingly advanced and often demand cleaner coals. While this applies particularly to coke making for metallurgical use, it also applies to both the energy generation industry and the cement industry.

2.4.2 Copper Production

Copper ores are mined by open pit and underground mining methods, with both methods being used at some mines. Almost all copper ores are oxide or sulfide compounds of copper. Oxide material is suitable for copper recovery through leaching, followed by solvent extraction and electrowinning (SX-EW). The oxide material is generally a weathered, near surface copper deposit mined by open-pit methods. With sulfides, flotation is used to make copper concentrates. Open-pit mines may also mine the deeper, unweathered, sulfide deposits below the oxides, but at a certain depth (which is determined by local conditions) underground mining is more economic. The choice of mining method is primarily influenced by geological factors such as the shape and size of the orebody, the spatial variation in ore grades throughout the orebody, and the location of the orebody relative to ground surface contours. Also of great importance are the strength and stability of both ore and host material.

Surface mining is used to produce the majority of the world's copper. Economics and technology dictate the final limits of an open-pit mine. Economic considerations include ore grade and tonnage, stripping ratio, operating cost, and capital cost; technological considerations include equipment, pit slope, bench geometry, and others. Mining production rotates around the truck haulage cycle times which, in turn, depend on the pit's depth (affecting the grade and length of haul roads) and the capacity of the trucks and loading equipment. For each site there is an optimum combination of pit design and equipment selection. Large open-pit copper operations use some of the largest mining machines available, but size is not the only consideration in equipment selections. Factors such as fuel economy and ability to operate in very hot or very cold conditions or at high altitude are also taken into consideration.

There are several underground mining methods used for copper deposits. Access to deep deposits is usually by vertical shafts, while shallow ore bodies too deep for open pit mining may be reached by a shaft, adit (horizontal tunnel), or decline (straight or spiral ramp). Block caving is a mining method that allows large blocks of an orebody to be undercut, resulting in the natural caving of that block of ore. Stoping methods are designed for different conditions of dip, width of deposit, character of ground and grade of ore. Cut-and-fill mining is best suited to steeply dipping veins and bedded deposits. In the cut-and-fill method, the ore is broken and removed from the stope, and then waste in the form of broken rock, sand and tailings is backfilled into the stope to within working distance of the roof .Whatever the mining method, ore is either trucked or hoisted to the surface and delivered to the primary ore stockpile. Underground mining is moving towards achieving the benefits of continuous processes as practiced in manufacturing industries. The cycle of drill, blast, load, and haul has been developed to a high level of efficiency, but further improvements are expected with increased automation of equipment and processes.

The economic copper grade at a given time and location depends on mining and extraction costs and the copper price. Occasionally wastes may be treated by hydrometallurgical methods. The waste dumps are leached with acid and ultimately the copper is recovered by SX-EW. However, this process may take several years and may not be economic without other production from the site. Copper is often produced in association with gold and silver, and in many cases other base metals such as cobalt, molybdenum, nickel, lead, and zinc.

The extraction from copper ores consists of a series of concentrating steps. Processes are designed to raise the grade of the extracted products. There are two commonly practiced procedures designed to separate the gangue content from the valuable components in copper sulfide ores. The first is concentration, which is to crush and grind the ore into particles, and then physically separate the sulfide particles from the gangue by mechanical methods to produce concentrates that mainly comprise copper minerals. The second is smelting, in which the concentrate is reacted in a furnace to chemically separate the copper and other nonferrous metals from other constituents, mainly iron, sulfur, and silica. This must be followed by a refining step to achieve the metal purity necessary for the market. For copper oxide ores, the copper is dissolved from the ore by sulfuric acid or another solvent, and the resulting solution is treated by solvent extraction, whereby the metal is recovered from the weak solution in a concentrated form suitable for electrowinning, thus bypassing the smelting stage. The face of copper production technology has changed dramatically with the rise of hydrometallurgical or aqueous techniques that process copper oxides and leachable sulfides such as chalcocite.

2.5 Mining Investment Risk Analysis

Mining operations represent an economic activity in which many decisions involve risk and uncertainty. There are many activities involved in current mining projects. Tasks include exploration, resource calculation, human resource planning, drilling, transportation, and closure, and in all of these the mining company must deal with local people, local and national governments, national and international standards, and even international organizations, both governmental and nongovernmental.

Many of the risks in a mining project are well known before operations begin, and the prudent organization will analyze and account for those risks before the investment decision is made. These major risk factors may be conveniently divided into five categories:

- Partner risk such as the partner’s qualifications and ability to manage projects.
- Technical risks such as resources, operating issues, and raw data reliability.
- Investment climate risks such as political or infrastructure problems.
- Market risks such as selling price and availability of markets.
- Economic risks such as rate of return, net present value, and payback period.

Investment risk may be analyzed and quantified in several ways. Control of risk is one of the prime responsibilities of a company’s senior managers. Those individuals often consider all the data and information provided by experts from inside and outside the company, including geologists, engineers, financial analysts, lawyers, and others, and then make their decision after a discussion of the risks, based on their combined experience and intuition. This approach relies on the experience and instinct of experienced individuals, and can be difficult to quantify. The decision methods may or may not be repeatable.

In the more systematic approach suggested here, a similar group of senior managers again analyzes and discusses data provided by experts; then each manager makes a numerical assessment of the risk to the project in each of several areas, as defined in a list of risk areas. The numerical assessments from each individual are then compiled to provide an overall quantification of the risk associated with the project, which is used as the basis for the investment decision. This approach still allows for input based on individual experience and intuition, but at the same time captures the individuals' assessments of risk numerically, and can thus be more repeatable. Table 2.2 shows a risk assessment matrix used in the past by K Company.

Table 2.2 K Company's risk assessment matrix

Major categories	Minor categories
Partner risk	Domestic partners Foreign partners
Technical risks	Project stages Geological issues Operating issues Production scale Reliability of data
Marketability	Standard of products
Investment climate	Political risks Permitting Infrastructure
Economic values	Internal rate of return Net present value Payback period

2.5.1 Monte Carlo Simulation

A more quantitative approach to risk assessment may also incorporate mathematical and statistical methods to assess the risk associated with a project.

Monte Carlo simulation uses random numbers to determine combination of events for simulated analysis. Consider a scenario in which there are several random events, each of which may or may not occur. Even when the probability of occurrence for each event is known, it may be difficult to calculate the probability of occurrence for each combination of events. In the Monte Carlo method, a random number generator is used to calculate probability for each combination of events, and the randomized calculation is repeated for many iterations, so that an estimate of the overall probability for each outcome can be estimated. Monte Carlo simulation has been applied to estimation of oil and gas reserves, business risk analysis, optimization of traffic signal systems, and in other applications in physical science, engineering, and game theory. It has even been used to calculate the value of the irrational number π to thousands of decimal places (Vose 2008).

When investments in mining projects are considered, it can be difficult to assess the overall risk associated with a project because there are too many influential risk factors with different kinds of uncertainties at the same time. Monte Carlo simulation is an effective way to solve this problem, and personal computer software is now available for this application. One program is @Risk software (Palisade Corporation 2010). The analysis of the output can help quantify the degree of risk for a given project. In this thesis, Monte Carlo simulation was performed by computer and applied to investment criteria for coal and copper mine projects (Davis 1995).

2.6 Risk Analysis with @Risk

2.6.1 How @Risk Software Works

@Risk software is used to model situations where decisions are made under uncertainty, using Monte Carlo Simulation. @Risk is particularly useful in problems faced by companies in the mining and natural resources sector. @Risk can be used to analyze the uncertainty associated with estimating the resources underground, the variable world prices for such resources, and the mining costs. Generally, there are four steps in using @Risk software.

- Review the project.
- Build and test the model.
- Run the Monte Carlo simulation.
- Review and analyze the result.

2.6.2 Sample Project

This section shows how to use @Risk software with a practical example of a coal mining project, illustrating how risk analysis techniques can be used to support decisions in the climate of uncertainty.

- Project description

  A mining company is considering developing a small open cut coal mine. All procedures such as feasibility study, engineering, and permitting have been done. This mine will produce 1 million tons of thermal coal annually with a 5-year mine life. Estimated capital costs are $ 150 million and operating costs are $ 65 per ton. An annual interest rate of 10% is assumed during the mine life.

Though a considerable amount of analysis has been done, there is still some economic uncertainty. Specifically, it is considered likely that the coal sale price will vary, and the overall value of project is likely to be quite sensitive to such variations. In the feasibility study, the coal sale price range predicted by investment banks was used for the economic analysis. The ranged from $100 to $135 per ton, with a mean of $117 per ton.

The objective of the @Risk analysis is to value the mining project on a discounted cash flow (DCF) basis, taking into account the impact of the economic uncertainty resulting from changes in coal price.

- Building and testing the model

Once the objectives of the model have been specified and the relationships between variables that can affect the outcome of the result have been defined, the model can be coded.

The economic analysis in a feasibility study is often calculated in a spreadsheet. Risk analysis capabilities can be easily added to a spreadsheet using @Risk, which functions directly as an add-in to Microsoft EXCEL, using new menus, toolbars, and custom distribution functions. In @Risk, the desired probability distribution is entered directly into a worksheet formula using the custom distribution functions. All of the commonly used distribution functions are available. In this example, a triangular distribution is used for the coal price. This is because the triangular distribution uses three easily identifiable parameters, the minimum, maximum, and mean, to describe a complete distribution, and often these are the only parameters known. In this case

RiskTriang (100,117,135) specifies a triangular distribution with minimum value of 100, a most likely value of 117, and a maximum value of 135.

In this example, the RiskTriang function is added into the spreadsheet cell in which the coal price appears. When the risk analysis is run, the program calculates the values in the spreadsheet many times, using a different, randomly selected value from the RiskTriang function for coal price in each iteration. The software compiles the results for selected key variables, and allows the presentation of those results in several different types of tables and graphs.

In this example, net cash flows and internal rates of return were tabulated and graphed.

The graphs on the following pages show the net cash flow (Figure 2.1) and net present value (Figure 2.2) each as a function of coal price. The results using mostly estimates show that the internal rate of return for the mine evaluation is 21.66% and a net present value at 10% of $ 43 million.

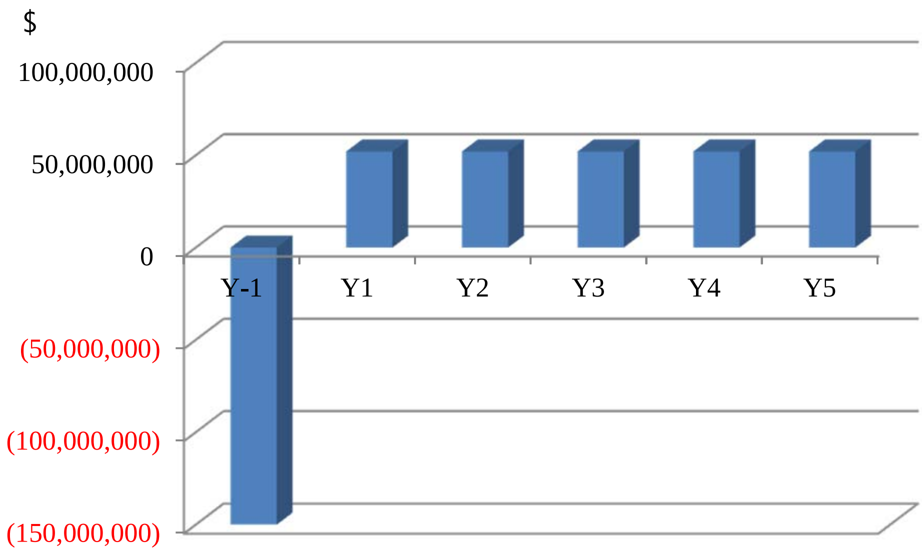


Figure 2.1 Annual net cash flows

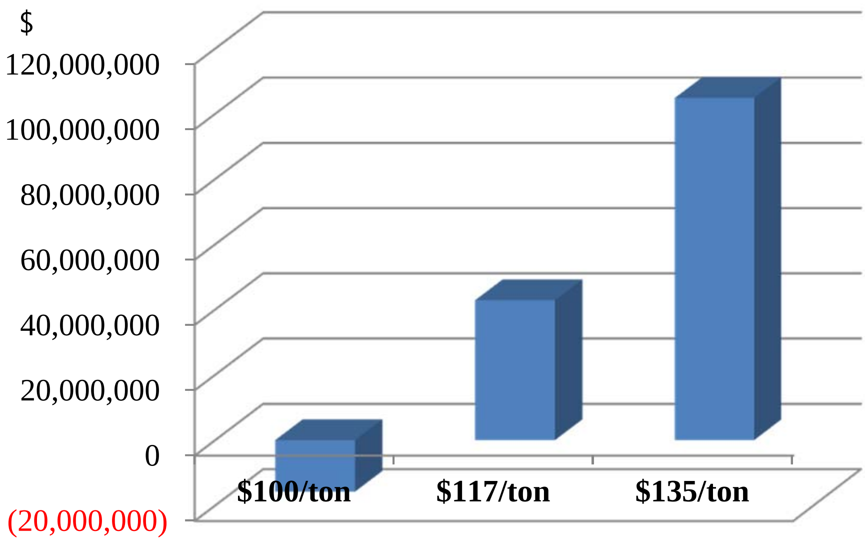


Figure 2.2 Net present values for three by coal prices

- Running the Monte Carlo simulation

To run a Monte Carlo simulation for this project evaluation, the number of iterations and the formats for the displaying the results are selected, as shown in Figure 2.3, which is a screen shot, taken as the simulation was running. The red bar at the top shows that the simulation is 52% completed, after 300 of the 10,000 iterations requested.

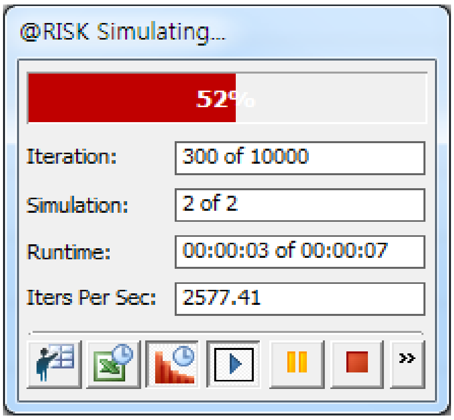


Figure 2.3 Simulating process

- Reviewing and analyzing the results

The risk analysis results will be displayed for analysis and reporting. Figure 2.4 shows that the average, expected IRR for the project is 21.4%, with a standard deviation of 6.4%. This figure also shows that there is 90% certainty that the IRR lies between 10.42% and 32.03%. In addition, Figure 2.5 shows that the net present value of the mine evaluation is $42 million with a standard deviation of $25 million. This figure also shows that the NPV lies between $1.5 million and $84.2 million, with 90% confidence interval.

The simulation features of risk analysis allow planners and executives to practice strategies to avoid results that would be 'painful' to the company. In addition, risk analysis simulation can provide management with the methods to test and validate operational forecasts. Risk analysis potentially can lead to better decisions because the decision-making team is better informed about the threats and opportunities presented by the uncertainties likely to arise in the future.

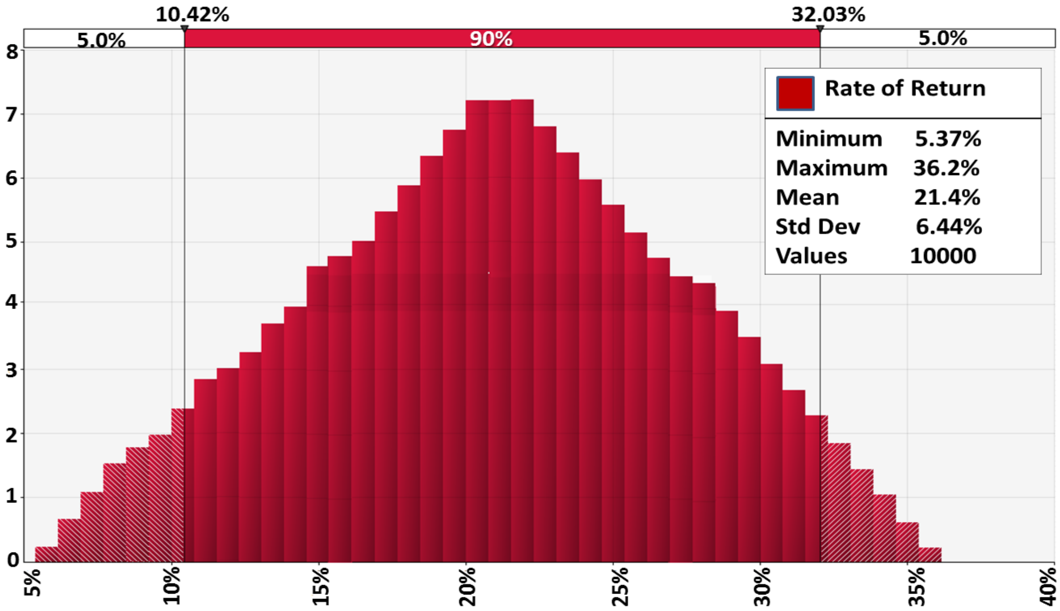


Figure 2.4 Distribution for IRR

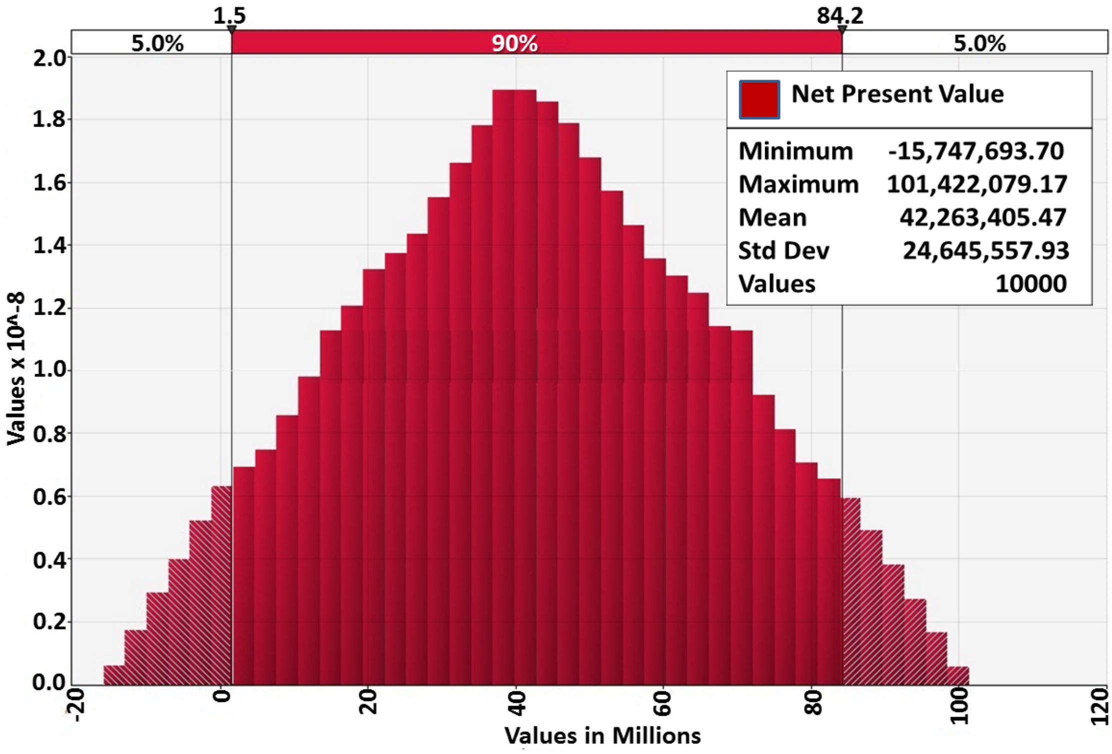


Figure 2.5 Distribution for NPV

2.6.3 The Importance of Model Testing and Demonstration

Whenever we contemplate investment in a mining project, several variables must be considered. Before software like @Risk was available, project risk analysis was made by combining single estimates of all of the variables for a given model to predict a result such as IRR or NPV. Singular estimates of model variables had to be used because calculating the model for a wide range of variables was simply impractical. Of course, in the real world, singular values for variables like commodity prices and inflation are known to be inaccurate, so the ability to estimate the expected value of project outcomes, based on a range of values for each key variable, is very useful.

With @Risk software to test, we can explicitly include the uncertainty present in our estimates to generate results that show all possible outcomes. Simulation with

@RISK combines all the uncertainties identified in a given situation so that those uncertainties may be anticipated in project planning. In this way, the full range of possible values for each variable can be considered, and a measure of likelihood of occurrence for each important outcome can be estimated.

Finally, the importance of clear communication cannot be overemphasized. @RISK provides formats that allow simple, graphic illustration of the risks associated with a project. These graphs are easily understood, and easily explained to others.

CHAPTER 3

OBJECTIVES

At any given time, a mining company may be exploring for new deposits or evaluating the expansion of existing projects, possibly as a result of the discovery of additional ores, an increase in commodity price, changes in the mining method, or the introduction of different technologies. In each case, additional capital investment will be required. Thus technical and economic studies will be required to form the basis for the investment decision to determine whether the projects under consideration meet the company's investment criteria, and whether they add value to the company.

The goal of this thesis is to provide insight into the methods currently being applied by mining companies when evaluating their new mineral project investments. The major criteria and evaluation tools by which the mining companies evaluate their capital budgeting internal rate of return, net present value, and payback period, usually used in combination.

Many companies have a minimum required rate of return, sometimes called the hurdle rate, which is highly project-dependent with primary factors being technical risks, market risks with certain commodities, and technical risks. In addition, some mining companies use the adjusted NPV method, in which a project's value is based on the sum of the present values of cash flows.

Some companies have additional criteria which must be met before an investment will be made. Some of these include:

- The project must generate positive cash flows at the lowest price projection in the analysis.
- The project will not invest in countries in Africa with high political risk.
- The project will include joint investment by more than one company, in a joint venture or similar arrangement.
- The project must be shown to be self-financing before development is begun.
- When a trading company is involved in the project, that company may want to have a pre-emptive or exclusive right to market the products of the project, to earn commissions.

There is no ready-made recipe for analysis of investment risk that applies in all situation but many of the major mining companies, such as BHP Billiton, Rio Tinto, and Anglo American have well documented procedures and checklists for each step of mining project evaluation, as well as specific criteria for investing in new projects (Bullock 2011). Unfortunately, these procedures, checklists, and criteria have not been published. Among the mining companies, K Company is late coming into the market for mining properties and projects. One of the goals of this thesis is to provide a system of procedures, checklists, and criteria for use in the evaluation of mining investments.

In that regard, there were three specific objectives in this thesis. The first was the development of a risk assessment matrix, similar to the one shown in Section 4.4. The second was the development of a computer model in the @Risk software to allow systematic quantification and analysis of risk, using the risk assessment matrix. The third was to demonstrate the @Risk model using data from investment projects previously executed by K Company.

CHAPTER 4

PROCEDURE

In this chapter, the author first analyzes instances in the past where K Company missed opportunities to invest in successful projects. The analysis includes discussion of the reasons for those missed opportunities. After that analysis, K Company's 23 existing coal and copper projects are reviewed and categorized to show the investment strategies involved and the postinvestment progress of those projects. Finally, following a discussion of current market conditions in the mining industry, and risks encountered in mining investments, the risk assessment matrix for K Company is presented and discussed.

4.1 Examples of Missed Investment Opportunities

4.1.1 The A Copper and Gold Project in Laos, Asia

This mining project is located in the Savannakhet Province, Laos. The Lao Government holds a 10% interest in the project, with foreign investors owning the other 90%. Operation of the open pit mine commenced in 2005. The processing plant is one of the most modern and technically sophisticated of its kind in Asia, employing leaching, solvent extraction, and electrowinning for recovery of copper and gold. It annually produces 65,000 tons of cathode copper and 93,000 ounces of gold.

K Company surveyed this project in 2001 and decided at that time not to invest because of identified political risks in Laos, such as the government's free-carried interest on the project, and the pervasiveness of corruption and graft. In addition, there were other perceived risks, including the low geological base potential, a very wet climate that would make operations difficult, insufficient raw data for decision making, and dissent from other investment partners. However, an Australian company invested in the project and during two years of development overcame several problems to successfully bring the property into production. The mine is now one of the largest copper and gold mines in Asia.

4.1.2 The B Coal Project in Mozambique, Africa

This coal project is located in northwestern Mozambique in the Changara District near Tete Province. The property is owned by an Australian mining company, and is spread over 24.74 square kilometers. It is one of the largest undeveloped coking coal projects known. The mine lies adjacent to the Benga project, which was the first hard-coking coal project in Africa and is currently under development by an Australian company and an Indian steel maker. While similar to Benga in many respects, the site of this project is much bigger. A definitive feasibility study on the project was started in 2011 with production scheduled to commence in 2014. The total coal reserves are estimated to be 9 billion tons, as of 2010. An Australian consulting company is evaluating the most favorable approach to development, including processing and logistics. The use of electric shovels with in-pit crushing and conveying systems is under consideration as a cost-efficient technique. The detailed mine plan will be analyzed in the feasibility study.

The mine site lies near Tete, the provincial capital. It has direct access to the Zambezi River. Major infrastructure including power, water, rail, and sealed roads will be developed to support the mine, requiring a huge capital expenditure.

K Company considered this project in 2009. After analysis and negotiation, a decision not to invest was made, based on insufficient geological data, limited infrastructure, Mozambique's mining law (which was considered unclear and risky), the owner's lack of experience in mine operation, and expectation of an unreasonably high initial investment. However, an Australian company continued to explore this project, and after two years the total resource estimate had increase five-fold. A major mining firm acquired a 50% interest in the Australian company in 2011.

4.1.3 The C Coal Project in Indonesia, Asia

This mining project is an operating open-cut coal mine in the Muara Lawn District of Kabupanten Muara Teweh in Central Kalimantan, Indonesia. This project is adjacent to the PT Marunda Graha Mineral Concession, and others, including several areas held by BHP Billiton. The mining concession contains two resource areas, which have 236 million tons as a resource basis. Production operations commenced in 2008 with less than a million tons produced to date. Run of mine (ROM) production rate is forecast to reach 3.6 million tons per year by 2012. More than 1,500 workers and six excavator and truck fleets are currently on site. The mine is remotely located, and the coal is trucked 35 km and barged 562 km to reach ship loading areas.

K Company surveyed this project in 2009, but for several reasons made no investment. First, even though there was a mine operating at the site, operating data were considered insufficient; second, there was uncertainty regarding Indonesia's new mining law for foreign investors; third, there were operating risks in developing some areas of the property, which lie in restricted national forest region; fourth, the owner lacked experience in the mining industry; and fifth, there was an expectation of an unreasonably high initial investment. The owner had tried to make a deal with several investors, but had not succeeded. However the company was successfully floated on the Indonesian stock market in 2010, and today the enterprise is valued at almost 2 billion dollars.

4.2 Review of K Company's Existing Projects

Since 1994, K Company has made many overseas investments. As of 2011, it has 35 projects in 15 different countries, and is focusing on investments in coal and copper, with 23 coal and copper projects.

4.2.1 K Company's Coal Projects

K Company is pursuing 11 bituminous coal projects, with four in the exploration phase, two in the development phase, and five in the production phase. Almost all projects are located in Australia, because of its good reputation, good economic policies, and sustained economic growth.

K Company purchased interest in a bituminous coal project in South Africa from an Australian-based company in 2010. This purchase is expected to help diversify Korea's coal supply. It also is expected to provide K Company with a bridgehead from which to pursue further investments African bituminous coal.

Many private Korean firms have invested in countries such as Australia, Indonesia, China, and Canada, but not yet entered into other countries with abundant coal resources but higher risks. Those countries include Russia, eastern African countries, and Mongolia, as discussed below.

- Mongolia

Mongolia is developing as a significant coal exporting nation due to its rich coal reserves and its proximity to China. Mongolian thermal coal exports reached approximately 4.3 million tons in 2010. Because it is landlocked, it is expected that a significant portion of Mongolia's coal exports will be directly consumed by China. However interest in Mongolia for other markets increased significantly in 2010 and the trend is expected to continue.

- Russia

In 2010, Russian thermal coal exports reached approximately 83 million tons due to improvements in the global financial market. Thermal coal exports from Russia are expected to rise with rising demand from the European nations and continued demand from developing Asia. The Republic of Korea imported 8 million tons of coal from Russia in 2011 (KITA 2012). However, rail bottlenecks from the operations to ports have limited Russia's coal exports. Companies such as Siberian Coal Energy Company (SUEK) and Mechel Steel are in the process of overcoming logistics difficulties by developing long-term contracts with Russian Railways and their own ports or port allocations. Thermal coal production in Russia's Far East, which is closer to Korea, is increasing, and given the short freight routes into Korea, use of Russian thermal coal is likely to increase in the medium to long term.

- The Republic of South Africa

South African thermal coal exports are expected to exceed 70 million tons in 2011. The Republic of Korea imported 2.3 million tons of South African coal in 2011 (KITA 2012). Although the distance between Korea and South Africa is comparatively large, Korea sometimes imports South African thermal coals if ocean freight rates are favorable compared to those from Australia. Rail capacities are key issues for South African exports and the ongoing consequences of the Black Economic Empowerment (BEE) policy are difficult to predict, posing another risk for new investors.

- Indonesia

Indonesia has been the world's largest exporter of thermal coal since 2005. In 2010, Indonesia exported approximately 237 million tons of thermal coal. In the short term and with expansion of operating mines and increasing greenfield projects coming online, Indonesia's export of thermal coal is expected to reach 248 million tons by 2012. The Republic of Korea imported 40 million tons of thermal coal from Indonesia in 2011 (KITA 2012). However, there are some risks for foreign investors. First, export growth from Indonesia is expected to be limited due to increasing domestic demand. Second, government intervention is likely to come in the form of domestic market obligation or taxes to deter increasing export levels and may constrain export capabilities. Third, illegal, unreported mining is estimated to account for approximately 5 to 10% of the total production, and is likely to increase. Nevertheless, there have been continuous project developments in the area.

4.2.2 K Company's Copper Projects

K Company has 12 copper projects, with four in the exploration phase, five in the development phase, and three in the production phase. Most of these investments were made in partnership with South Korea's sole copper smelter, LS Nikko Copper. Currently, both K Company and LS Nikko Copper would like to acquire an existing company, with existing potential projects, to serve as a platform for greater involvement in projects in Central and South America, with plans for longer term resources development. Private Korean firms have invested in copper projects in Chile, Peru, China, and the United States, but most of these projects are only in the development phase. This is because metal projects are more expensive and risky than coal projects, so more money is required for investment in late-stage projects. Many countries which have copper resources have at some point nationalized some or all of those resources, which casts some doubt on new investment in those countries. However, some governments are trying to change the mining regulations and tax regimes related to mining, to attract more foreign investment. Often these changes involve a combination of decreasing of government ownership or royalties and heightened environmental standards.

4.3 Mining Investment Market Conditions and Defined Risk Factors

As global demand for mineral commodities like coal, copper, nickel, gold, and aluminum continues or increases, mining companies are venturing into less developed countries to find and exploit new ore deposits. Major ore deposits are increasingly difficult to find in developed countries such as the United States, Canada, and Australia. Operating costs may also be higher in developed countries, because of more extensive regulations and enforcement regimes.

Global mining companies who were once reluctant to assume the risks encountered in countries like the Democratic Republic of Congo and other African and South American countries are now increasingly finding it necessary to invest in such places to maintain or grow reserves and meet global demand for mineral commodities. For instance, Freeport McMoRan's investment in Tenke Fungurume copper and cobalt mine in the Democratic Republic of Congo shows the significant risks mining companies are assuming by investing in the developing world (Burns 2007).

The risks mining companies assume when investing in less developed countries include extreme political and social risk, poor safety conditions, government corruption, lack of infrastructure to support mining operations, and inadequate supply networks for fuel, consumables, supplies, and spare parts. To the extent that mining companies expand into such countries, their risk profiles will change dramatically and investment decisions will mirror those changes.

K Company's missed investment opportunities and its existing projects illustrate the risks that mining companies often must assume by investing in projects in undeveloped countries. Those risks include:

1. Political and social risks

   Undeveloped countries usually have less stable governments and social environments, resulting from higher levels of poverty and infectious diseases, and other conditions. Investment contracts and other legal agreements can be instantly invalidated by an unexpected regime change. Environmental requirements, tax stabilization agreements, and other important operating constraints can sometimes be changed or invalidated at the whim of one or more government officials, and there may be no legal recourse. Furthermore, mining companies are often targets for social protest as has been demonstrated by the periodic suspension of operations like Newmont's Yanacocha and Conga projects in Peru, and Freeport McMoRan's operations in Indonesia (Indian Country 2012, Reuters Africa 2012). Mining projects may even face the threat of nationalization in countries like Venezuela and Bolivia, whose current governments have a socialist agenda.

2. Poor safety conditions

   Many undeveloped countries suffer from recurring political and social unrest, and may at times be in a virtual state of civil war, with destabilizing insurgent groups of factions competing for power. Mining projects often operate in remote rural areas where help from government militias is not readily available when needed. It is not uncommon for mining companies to staff their own militias to ward off attacks from insurgents at least long enough for government troops to arrive.
   In addition, adequate medical facilities are often not available in areas mining companies are operating, so those companies must staff their own medical facilities to handle emergencies.

3. Government corruption

   Government corruption may be the norm in an undeveloped country, from the highest level of government down to the local police force. Mining companies may be faced with demands for bribes to move forward with construction and development of projects or to sustain operations once a project is underway. This is a particularly difficult scenario for mining companies from countries like the U.S.A., whose national laws prohibit such practices (Goldbarg 2000, Johnson 1998).

4. Limited infrastructure

   Undeveloped countries often lack the infrastructure needed to support mining projects, such as railways, paved roads and highways, electric power generation facilities, power lines, etc. Mining companies may have to construct this infrastructure as part of the initial capital cost of a project, thus increasing substantially the initial investment in the project.

5. Limited availability of laborers and other necessities

   Undeveloped countries may lack sufficient local industry to provide a trained labor pool from which mining companies can hire. In addition, supplies of fuel, consumables, operating supplies, and spare parts may be limited. This can be particularly difficult during the construction and development phase of a project when significant quantities of such items are required. Mining companies may have to import workers, equipment, and supplies required to construct, develop, and even operate mining projects.

6. Insufficient information about the prospective project

   In an underdeveloped company, it can be difficult or even impossible to find all the information that a company may wish to consider when analyzing a prospective investment. A company may reasonably choose not to pursue an investment under such conditions.

4.4 Development of Risk Assessment Matrix

The risks considered by K Company when evaluating mining projects were listed earlier, in Table 2.2. Based on the author's experience, and on interviews with K Company personnel, the list in Table 4.1 was modified to quantify the proportion of the project risk assigned to each category and the ranking criteria for those categories.

Table 4.1 shows the risk assessment matrix, with numerical values included. The numerical values shown are based K Company's 23 existing coal and copper projects all over the world. The risk criteria are divided into major and minor categories. The major categories are partner risk, technical risks, marketability, investment climate, and economic value. Each major category is divided into minor categories, showing important factors to consider in analysis of the five major risks.

Partner risk is listed first because, for K Company, partner risk is an almost unavoidable criterion. One of the main reasons K Company was founded was to support domestic companies. In almost every case, when K Company has an opportunity to invest new project, K Company usually organizes a consortium and invites several end-users or trading companies to join. In these cases, partner risk must be considered. In addition, many projects also involve foreign partners, usually the owner or operator mining property under consideration. In these cases, K Company must consider each partner's reputation or working experience in the mining industry. K Company prefers senior mining companies to junior companies, because operating experience is one of the most important considerations in the mining field. However investments are made with more junior companies when their opportunities are good.

TABLE 4.1 K Company's developed risk assessment matrix

Major (Proportion)	Minor (Weight)		Description
Partner risk (5%)	Domestic partners (40%)	A	Good finance condition
		B	Bad finance condition
	Foreign partners (60%)	A	Listed company
		B	No listed company
		C	No corporate entity
Technical risks (50%)	Project stage risks (20%)	A	Developing or operating projects
		B	Scoping, preliminary, and feasibility study
		C	Exploration
	Geological issues (30%)	A	Measured & indicated resources, or reserves
		B	Inferred resources
		C	No source statement
	Operating issues (30%)	A	Standard extraction
		C	New technology proposed
	Production scale risk (10%)	A	Coal 2 Mt/yr, Copper 100 ktpy
		B	Medium production
		C	Coal 1 Mt/yr, Copper 50 ktpy
	Data reliability (10%)	A	International standards observed
		B	Standards not observed
		C	Insufficient material to evaluate
Market-ability (5%)	Product Standard (100%)	A	Suitable for Korean market
		C	Specific market uncertain
Investment climate (20%)	Political risk (40%)	A	Standard and Poor's, Fitch A
		B	Standard and Poor's, Fitch B
		C	Standard and Poor's, Fitch below B
	Permitting (30%)	A	Mining permit and EIS approved
		B	EIS approval in process
		C	None
	Infrastructure (30%)	A	Secured transportation, power, water, etc.
		B	Available transportation, power, water, etc.
		C	Partly available
Economic values (25%)	IRR (20%)	A	20%
		B	15%
		C	Less than 10%
	NPV(60%)	-	Positive value
	PBP (20%)	-	Maximum 12 years

Technical risk is listed second, and includes five minor components. Risks associated with project execution derive from unknowns in exploration, project planning, project developing, construction, and operation.

Geological risk is one of the most important factors to consider in evaluating operating risk. Quality of exploration is critical. Many mining projects have insufficient or poor data, which leads to sub-optimal mine planning in the future. Most companies rely on resources and reserves estimated using standards such as the Australian Joint Ore Reserves Committee (JORC code) and Canadian National Instrument (NI) 43-101 (JORC 2004, CSA 2011). Using such standards, geological risk is determined by assessing the accuracy and reliability of the resource and reserve estimates, based on standard classifications such as measured, indicated, and inferred for resources, or proved and probable for reserves.

Operating risks are related to mining and metallurgical methods that will be used in the project, and are assessed based on how often and how successfully such methods have been used in the past, not only on a worldwide basis, but also in the target area and by the operating partner for the project being considered.

Production scale risk is assessed based on the expected annual production volume. In many cases, there is a minimum production amount required for certain commodities, and this must be met. In addition, risks are different for large- and small-scale operations, and those differences must be included. K Company has a minimum required production amounts for coal and copper, based on its experience with previous investments. The minimum required annual production is 1 million tons of coal and 50,000 tons of refined copper.

Finally, the reliability of data category is used to provide an overall assessment of the company's confidence level in the information available. This assessment includes such factors as how recently the data were collected and the qualifications and experience of those gathering and analyzing the data.

The third major risk category is marketability of products. This is specifically related to whether the products conform to the requirements of Korean markets and consumers. For example the specifications for thermal coal are 17% maximum ash content and 6,400 kcal/kg minimum calorific value, on an as-received basis. Recall that one of K Company's mandates is to secure interest in sources of products for use in Korean industry. If the products of a given project are not expected to conform to Korean standards, that project will not be considered a satisfactory investment for K Company.

Investment climate is the fourth major risk category. It includes the risks associated with social and economic conditions in the country where the project is located, along with risks related to permitting and infrastructure. Mining companies should carefully consider conditions relating to political stability, government corruption, infrastructure status, local support services, and availability of skilled local personnel in the country where they want to invest. For rating investment climate risk, K Company's internal standard is that investments should be made according to global standard ratings from credit rating agencies such as Standard and Poor's and Fitch Ratings. These companies are involved in Nationally Recognized Statistical Rating Organizations (NRSRO) designated by the U.S. Securities and Exchange Commission in 1975, with Moody's (NRSRO 2012). Standard and Poor's (S and P) is a financial services company based in the United States that publishes financial research and analysis (Standard and Poor's 2012). Fitch Ratings is a similar firm based in France (Fitch 2012). As credit rating agencies, these companies issue a credit ratings of corporations and countries, and offer to provide value beyond the ratings through independent and prospective credit opinions, research, and data. They provide investors with market intelligence in the form of credit ratings, indices, investment research and risk evaluations.

When a new mining project is proposed, several legal and regulatory requirements must be satisfied, including an environmental impact statement (EIS) or similar document, one or more mining permits, and clear land status. Continual changes in regulations, mining laws, and tax regimes create uncertainty and sovereign risk. With the internet widely available, issues occurring at an operation in one country can become the concerns and examples to be used against a completely unrelated mining project elsewhere. Permitting delays are now a global issue. In this regard, it is important to consider potential delays in receiving permits due to bureaucratic and other delays. K Company has requirements for permitting risks in a prospective investment, depending on permit approval progress. Infrastructure is also an important consideration. Many undeveloped mineral deposits are located in remote areas of undeveloped countries, and the establishment of infrastructure will be the key to development of these projects. Specifically, rail and port facilities are very important in bringing products from mine sites to markets, and these facilities, which are very expensive, take a long time to construct. Typically, mining companies negotiate with governments for infrastructure requirements. K Company has defined requirements for infrastructure related to prospective investments. The infrastructure needs are rated by how many elements such as transportation, electricity, water supply, and labor were secured or available.

The final major parameter is an assessment of economic value, based on the expected IRR, NPV, and payback period. K Company has minimum required values for IRR, depending on project status and location. The value scale goes from 9% to 25%. However, the minimum required IRR for exploration projects are higher than those for operating projects. Generally exploration projects are more risky than developing or operating projects. When investors take part in an exploration project, they usually expect to invest a smaller amount of money, at a higher risk. On the other hand, they need much more money to secure a position in a developing or operating project, which is expected to have already overcome several risk factors, especially geological risk, which are the most significant. The net present value is expected to be positive, based on an independent analysis by K Company or its designate, or on an analysis provided by the project's owner or operator. Usually, the NPV is considered to be the current worth of a project. Depending on the execution status of the project, it may be thought of as a reasonable purchase price. However, the seller or sellers may expect a premium (above the NPV) as compensation for their previous investment in the project, and the risk that was associated with that investment. In addition, the NPV may be calculated by different rates of return in project conditions. Of course this must consider when evaluating projects. K Company also expects that a proposed investment have a maximum payback period of 12 years, depending on the proposed mine life and location. If the investment has high expected risk in other areas, the payback period is expected to be shorter, to minimize exposure to those risks.

CHAPTER 5

RESULTS AND DISCUSSION

The preceding chapters discussed the importance of mineral resources to the economy of the Republic of Korea, and the function of the national company (here called K Company) in securing the continuing supply of those resources. Further discussion focused on the risks inherent in mining investments, and on methods that may be used to understand, quantify, and reduce those risks. Finally, two types of projects from K Company's recent activities are reviewed: first, investment opportunities that were abandoned as being too risky, but later proved to be profitable and attractive, and second, current investments in copper and coal projects. Based on those projects, a quantified risk assessment matrix for K Company's investments was developed, as shown in Table 4.1.

This chapter will discuss the development of an improved risk assessment matrix, constructed by surveying 31 experts from the mining industry. The incorporation of that improved risk assessment matrix into a probabilistic model, using @Risk software, will be explained, and examples of the use of the model will be presented. It is suggested that the use of this method will facilitate more rational and consistent investment decisions, which will allow K Company (and other organizations) to develop more precise business plans for developing overseas mineral resources. The proposed model and the associated risk assessment matrix will lead to reduction of the risks associated with mineral investments by facilitating systematic research and analysis of the technical and economic feasibility of mining projects.

5.1 Development of Modified Risk Assessment Matrix

A survey of 31 mining experts was taken to determine what current practice is being used when evaluating minerals investments. Specifically, this survey attempted to determine which risk factors are being employed and how they are weighted in the analysis of mining project risk. The survey also asked respondents to report the minimum rate of return used by their organizations in rating prospective investments.

The survey was performed by email and telephone. The respondents were current or retired employees of mining companies, mining consultants, commodity trading companies, and end users of minerals that also participate in mining projects.

Individuals from the United States, the Republic of Korea, Canada, Australia, Japan, the Republic of South Africa, Chile, and the United Kingdom responded to the survey (Figure 5.1). Eleven were from Asia, one from Europe, 11 from America, two from Africa, and six from Oceania (Figure 5.2). The companies represented ranged in size from almost no annual revenue to $ 16 billion in annual sales as of 2010.

Table 5.1 shows the affiliations of survey respondents. Their titles are vice president, former vice president, chief executive officer, chief operating officer, managing director, director, senior manager, manager, mine head, mine manager, former mine manger, former senior manager, professor, and consultant.

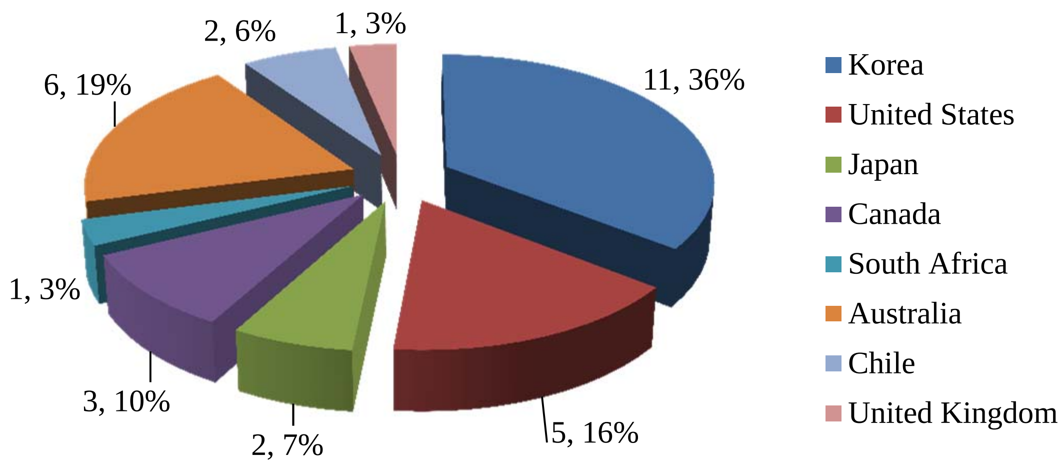


FIGURE 5.1 Survey respondents, by country

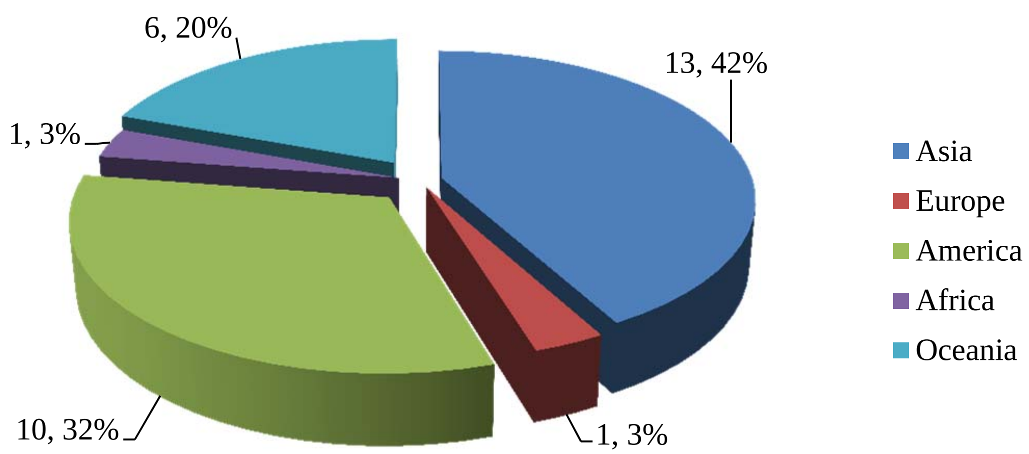


FIGURE 5.2 Survey respondents, by continent

TABLE 5.1 Affiliations of survey respondents

Country	Names
Korea (11 firms)	Pohang Steel Corporation (POSCO) Hyundai Steel Corporation Korea Electric Power Corporation (KEPCO) 3 Subsidiaries of KEPCO LG International Corporation Samsung Construction & Trading Corporation LS Nikko Copper SK Networks Corporation Daewoo International Corporation
United States (5 firms)	Cliff Natural Resources Norwest Corporation Jipangu International BHP New Mexico Coal Arvenut Resources
Australia (6 firms)	Coal and Allied Limited Whitehaven Coal Limited BHP Billiton Mitsubishi Alliance (BMA) Yancoal Australia Limited Palaris Mining Limited Runge Limited
Japan (2 firms)	Idemistu Kosan Corporation Itochu Corporation
Canada (3 firms)	Inmet Mining Corporation Lundin Mining Corporation Coffey Mining
South Africa (1firm)	Frontier Resources
Chile (2 firms)	National Copper Corporation of Chile (CODELCO, Corporación Nacional del Cobre de Chile) El Bronce Copper
United Kingdom (1 firm)	SRK Consulting

In the survey, the experts were asked to consider the risk matrix described in Chapter 4, then to evaluate the weighting factors shown as percentages in Table 4.1 and modify them based on their experience and opinions. The following sections consider each major risk factor, showing how the experts rated the risks listed in Figure 4.1. For each major risk, the minimum, average, and maximum investment assessment proportions indicated by the experts are shown. Similarly, the table shows the minimum, average, and maximum weighting factors for the minor categories associated with each major risk category, as indicated by the experts.

5.1.1 Partner Risk

As explained in Section 4.4, K Company must consider both domestic and foreign partners. Table 5.2 shows the average proportion for partner risk is 8% and the range of partner risk is from 5% to 30%. The weight assigned to domestic partner risk is 34.5%, with a range of 10% to 60%; for foreign partner risk it is 65.5%, with range of 40% to 90%. For domestic partners, the major and perhaps the only criterion is the partner’s financial condition. For foreign partners, financial condition should be considered in combination with the level of corporate and legal organization. In particular, the capabilities of the management team, partner’s financial condition, and its ability of secure funding for the project in question are essential considerations. These considerations are often made difficult by the fact the bigger companies want to operate projects by themselves, while the smaller (and often less qualified) companies are interested in working with a partner, to decrease mining risks.

TABLE 5.2 The partner risk matrix

Major Categories	Proportion	Minor Categories	Weight	Grade	Description
Partner risk	8% Min 5% Max 30%	Domestic partners	34.5% Min 10% Max 60%	A	Financially strong
				B	Financially weak
		Foreign partners	65.5% Min 40% Max 90%	A	Listed company, senior company, or with operating cash flow
				B	Private company, junior company, or in poor finances
				C	No corporate entity

5.1.2 Technical Risks

As explained in Section 4.4, technical risks are the most critical factor in K Company's investment analysis. Table 5.3 shows that the average assessment proportion assigned by the experts to technical risks is 43.2% with range of 25% to 50%. Most experts considered technical risks the most important of the major risks among the five major categories.

TABLE 5.3 The technical risks matrix

Major Categories	Proportion	Minor Categories	Weight	Grade	Description
Technical risks	43.2% Min 25% Max 50%	Project execution risk	17.3% Min 5% Max 20%	A	Developing or operating
				B	Engineering study (Scoping Study, Pre F/S, F/S)
				C	Exploration
		Geological risk	38.6% Min 20% Max 50%	A	Measured & indicated resources, or proven & probable reserves
				B	Inferred resources
				C	No source statement
		Operating risk	20.7% Min 10% Max 40%	A	Standard extraction
				C	New technology proposed
		Production scale risk	13% Min 5% Max 30%	A	Coal – 2 Mt/yr, Copper – 100 ktpy
				B	Medium production
				C	Coal - less than 1 Mt/yr Copper - less than 50 ktpy
		Data reliability	10.5% Min 0% Max 20%	A	International standard applied
				B	Domestic standard
				C	No standard

The weighted average of project execution risk is 17.3% with range of 5% to 20%. In project execution, the initial stage is always more risky, but it also carries a lower cost. Thus there is a range of competing factors such as cost, approval risk, construction risk, and geological uncertainty. In the case of geological risk, the weighted average is 38.6%, varying from 20% to 50%. The experts considered geological risk as the most important factor among the technical risks, in agreement with K Company. Many of the experts mentioned the importance of using definitions of resources and reserves from international standard such as those previously cited (JORC 2004, CSA 2011).

Experts from some medium- and small-sized mining companies indicated that their companies require a minimum grade when they determine to invest or develop copper projects. In sulfide deposits, copper grade should be greater than 0.5 % for open cut mining and greater than 1% for underground mining. In oxide deposits, copper grade should be greater than 0.3% for open cut mining. The average minimum size for a copper reserve to justify investment is 10 million tons contained copper. In contrast, the bigger companies are willing to invest in prospects with lower grades, because they can finance bigger operations and achieve economies of scale that result in lower unit costs.

For operating risk, the weighted average for investment assessment is 20.7%, varying from 10% to 40%. Operating risk is the second most important among the technical risks. The quality of the feasibility study and execution planning for a project have a big impact on the ultimate success of an operation. These require good understanding of geology, ore quality, and product markets, as well as proper equipment selection, good mine planning and production management, and adequate process testing leading to design of an appropriate processing facility. The weighted average of production scale risk is 13%, with range of 5% to 30%. The production size required for investment depends on company size and project specifics, and the opinions of the respondents varied considerably. Experts from some coal mining companies indicated that a good project should be 5 million to more than 50 million tons of coal per year. On the other hand, representatives of copper companies expected annual production from 100,000 tons to 1.8 million tons of copper. The production scales shown are relatively small, based on the scale of investments planned by K Company. The determination of appropriate production size must be supported by robust financial analysis, thorough tradeoff studies, and excellent engineering and technical assessments.

In fact, all risk factors in the technical risks category depend on the reliability of data. The accuracy of data affects all the other factors in this category. The weighted average assigned by the experts to data reliability is 10.5%, with range of 0% to 20%. Major companies may be less concerned about data reliability because they often have their own properties which are ready to develop with good in-house geologists and engineers.

5.1.3 Marketability

Table 5.4 shows the experts' weighting of marketability risk. The weighted average investment proportion is 8.6%, with a range of 5 to 25%. Most trading companies put great value on marketability, because the profit earned in trading is their main source of revenue. Dormant mining projects are usually more difficult to develop than operating projects. Marketability may also be affected by the location of the project, or if the product is of low quality, compared to competitors' products.

TABLE 5.4 The marketability matrix

Major Categories	Proportion	Minor Categories	Weight	Grade and description	
Marketability	8.6% Min 5% Max 25%	Product standard	100%	A	Suitable for South Korea
				B	Suitable for foreign market
				C	Market uncertainty

5.1.4 Investment Climate

Table 5.5 shows that investment assessment proportion for investment climate risk was ranked by the experts at 18.2%, over a range of 10% to 30%. This ranking made investment risk the third most important factor in assessing investment risk. For the country risks associated with investment climate, the weighted average is 35.2%, and varied from 10% to 50%. The experts considered country risk the most important factor among the investment climate.

TABLE 5.5 The investment climate matrix

Major Categories	Proportion	Minor Categories	Weight	Grade and description	
Investment climate	18.2% Min 10% Max 30%	Country risks	35.2% Min 10% Max 50%	A	Standard and Poor's A, Fitch A, Fraser top 15
				B	Standard and Poor's B, Fitch B, Fraser top 30
				C	Less than above
		Permitting	31.1% Min 20% Max 50%	A	EIS and mining permit approved, cleared land status
				B	EIS approval in process
				C	None
		Infra -structure	33.6% Min 20% Max 60%	A	Secured transportation, power, water, labor
				B	Available transportation, power, water, labor
				C	Two elements available

Sources : Standard & Poor's 2012; Fitch Rating 2012; Fraser 2011

The matrix sent to experts for evaluation included some suggested guidelines for rating political risk, based on rating provided by financial services companies such as the Fraser Institute, Standard and Poor’s, and Fitch Ratings, as discussed in Chapter 4. The Fraser Institute, which is not used by K Company, is an independent nonpartisan research and educational organization based in Canada. Since 1997, the Fraser Institute has annually published “Survey of Mining Companies.” It provides an analysis of the mineral investment climate in the world’s major mining regions, and includes consideration of public policy factors such as taxation and regulation. The survey includes 79 different jurisdictions in seven regions of the world (Fraser 2011). Some companies are hesitant to invest in countries that are considered extremely risky, such as some African countries. Recent investments by some of the major mining companies suggest that they are, at least in some instances, willing to bear this risk. The experts were asked to consider permitting status on the basis of the degree of completion of applicable environmental impact statements. While standards certainly vary among countries, this is considered a reasonable guideline. In case of permitting, the weighted average is 31.1%, varying over a range of 20% to 50%. Finally, those surveyed were asked to consider specific and important elements of the required infrastructure. The weighted average is 33.6% with a range from 20% to 60%.

5.1.5 Economic Values

Detailed financial analysis must be supported by a range of sophisticated financial risk tools. Table 5.6 shows the experts’ weightings of factors in the economic values matrix.

TABLE 5.6 The economic values matrix

Major Categories	Proportion	Minor Categories	Weight	Grade and description	
Economic Values	22% Min 10% Max 40%	IRR	23% Min 15% Max 40%	A	Greater than 19%
				B	Greater than 15%
				C	Less than 10%
		NPV	57.7% Min 40% Max 70%	A	Positive NPV
				C	Negative NPV
		PBP	19.3% Min 10% Max 20%	A	Less than 6 years
				B	Less than 12 years
				C	Greater than 12 years

The weighted average of economic values is 22%. It is the second highest factor among the major risks. The range of economic values is from 10% to 40%. All companies that were surveyed indicated that they have their own required IRR (or hurdle rate). The average weight for IRR is 23%, and values range from 15% to 40%. The respondents indicated that, in most cases, their companies preferred projects where the IRR is 10% to 20%, depending on project status and location. In case of NPV, the weighted average is 57.7%, with a range of 40% to 70%. It is the highest ranked factor among the economic factors. According to the survey results, NPV generally plays a major role in decision making by larger firms. The responses in the survey regarding payback period varied considerably. The weighted average is 19.3%, varying from 10% to 20%. The survey indicates that payback period is relatively less important than other factors but all companies, especially the smaller ones, prefer the payback period to be short. Most companies hope to see less than 6 to 12 years in payback period.

The modified risk assessment matrix, based on the opinions of the 31 experts surveyed, is shown in Table 5.7. The weight for each minor factor is determined from grade assigned to that factor. The applied percentages for each grade were based on K Company’s practices, with some slight modifications as suggested experts’ experience.

TABLE 5.7 The improved risk assessment matrix

Major	Pro-portion	Minor	Weight	Grade	Description	Applied %
Partner risk	8%	Domestic partners	34.5%	A	Financially strong	100%
				B	Financially weak	50%
		Foreign partners	65.5%	A	Listed company	100%
				B	Private company	50%
				C	No corporate entity	0%
Techni-cal risks	43.2%	Project execution	17.3%	A	Developing or operating	100%
				B	Engineering study	50%
				C	Exploration	25%
		Geological risk	38.6%	A	Measured & indicated resources, or reserves	100%
				B	Inferred resources	50%
				C	No source statement	0%
		Operating risk	20.7%	A	Standard extraction	100%
				C	New technology proposed	25%
		Production scale risk	13.0%	A	Coal 2 Mt/yr, Copper 100 ktpy	100%
				B	Median production	50%
				C	Coal - less than 1 Mt/yr Copper - less than 50 ktpy	0%
		Data Reliability	10.5%	A	International standard applied	100%
				B	Domestic standard	40%
				C	No standard	0%
Market-ability	8.6%	Product Standard	100%	A	Suitable for South Korea	100%
				B	Suitable for foreign market	50%
				C	Market uncertainty	0%
Invest-ment climate	18.2%	Country risks	35.2%	A	S and P, Fitch A, Fraser 15	100%
				B	S and P, Fitch A, Fraser 30	50%
				C	Less than above	0%
		Permitting	31.1%	A	EIS and mining permit	100%
				B	EIS approval in process	50%
				C	None	0%
		Infra -structure	33.6%	A	Secured infrastructure	100%
				B	Available infrastructure	50%
				C	Limited infrastructure	20%
Econo-mic values	22%	IRR	23.0%	A	Greater than 19%	100%
				B	Greater than 15%	75%
				C	Less than 10%	25%
		NPV	57.7%	A	Positive NPV	100%
				C	Negative NPV	0%
		PBP	19.3%	A	Less than 6 years	100%
				B	Less than 12 years	50%
				C	Greater than 12 years	0%

5.2 Development of the @Risk Model Using the Risk Assessment Matrix

5.2.1 Model Construction

This section shows the development of a computer model using @Risk software to allow systematic quantification and analysis of risk, using the risk assessment matrix. Generally the procedure is:

1. Enter a distribution function
2. Select output cell and alter settings such as number of iteration
3. Run the Monte Carlo simulation
4. View the results and graphs

The first step is to load Microsoft Excel and @Risk software by selecting “@Risk 5.7 for Excel” in the Palisade Decision Tools group on the Windows Programs menu, and then open the risk assessment matrix. Figure 5.3 shows part of a sample risk assessment matrix, with rankings entered for each of the minor categories. To illustrate the use of @Risk, we assume that, in this case, the partner risk was not well defined, so the risk rating will be calculated over range of values for that risk.

MINING PROJECT RISK ASSESSMENT MATRIX

INVESTMENT OPPORTUNITY SCORE

	Major Categories	Investment Assessment Proportion	Minor Categories	Weight		Descriptions
	Partners' risk	8.0%	Domestic	34.5%	A	financially strong
					B	financially weak
			Foreign	65.5%	A	Listed company, or with operating cash flow
					B	Private company, or in poor finances
					C	No corporate entity

FIGURE 5.3 The risk assessment matrix

Second, start a worksheet and enter the distribution function. @Risk allows definition of distribution functions graphically or by typing the distribution function directly in a cell. To check that the function has been entered correctly, click the Define Distribution icon on the @Risk toolbar and a graph of the distribution will be displayed. Click OK to add the function to the cell in the worksheet.

Next is to define a range of distribution for the value or values that will be varied in the simulation, in this case partner risk. The triangular distribution is three easily identifiable to describe a complete distribution. As explained in Section 2.6.2, the distribution function, RiskTriang (minimum, most likely, and maximum) takes arguments specifying the minimum, most likely, or maximum possible value for the uncertain input. These values specify a triangular distribution with minimum value of 17.25, a most likely value of 25.875, and a maximum value of 34.5 (Figure 5.4). All the other risk factors are defined in the same manner.

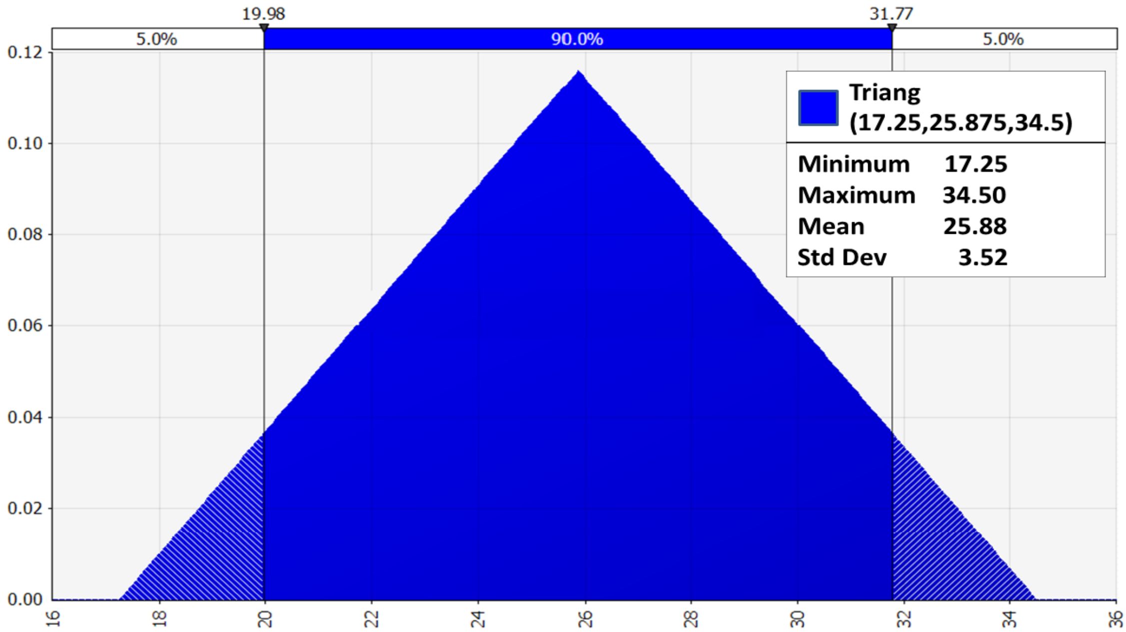


FIGURE 5.4 Defining a range of distribution

The third step in designing a simulation model is to select the output ranges on the @Risk toolbar. At least one output cell must be designated to anchor the output range (Figure 5.5), and care must be taken that the output does not write over existing data. Clicking OK adds the function to the cell in the worksheet, as shown in Figure 5.6. After the simulation settings, such as number of iterations, number of simulations, etc., are defined, the simulation is started by clicking Start Simulation on the @Risk toolbar.

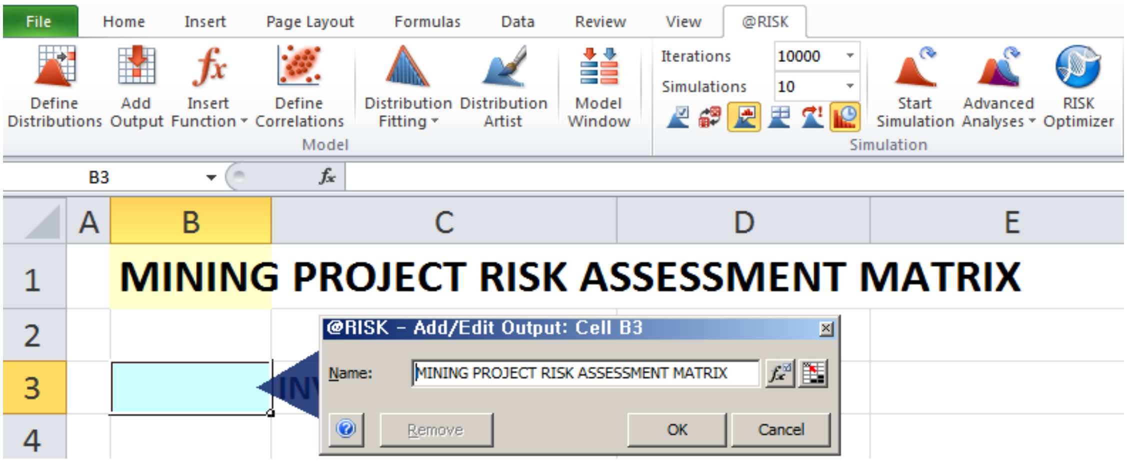


FIGURE 5.5 Selection of the output range

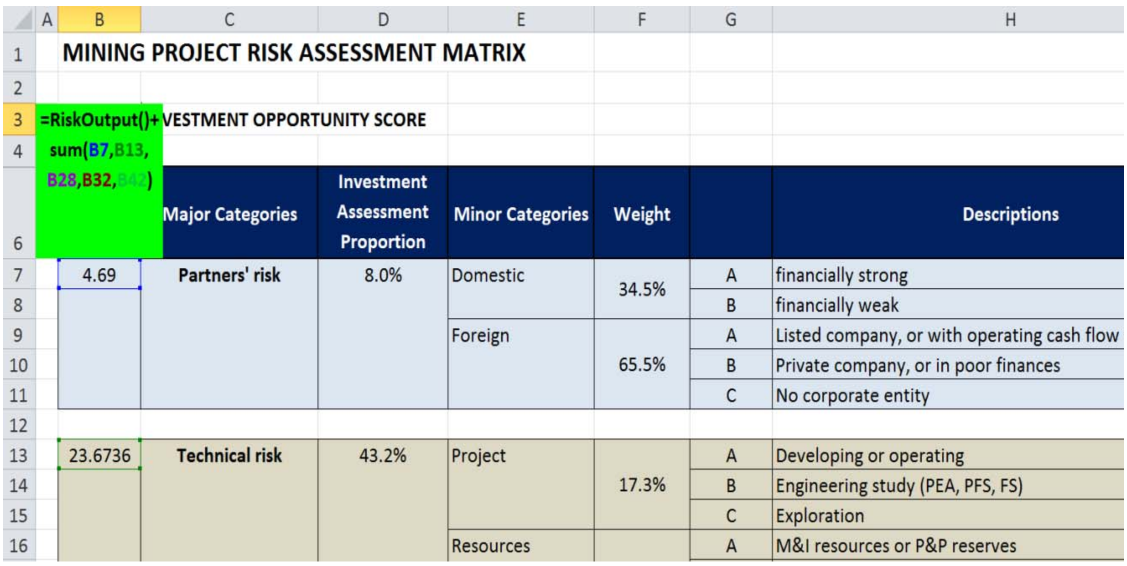


FIGURE 5.6 Output range added

When the simulation is finished, the results may be viewed as graphs. Figure 5.7 shows that the average of the investment opportunity scores calculated by @Risk for this mineral property is 54.68, with a standard deviation of 5.68 points. This graph also shows that there 90% of the calculated values lie between 45.31 and 63.96, which indicates a 90% confidence interval for the investment opportunity score for this example.

Alternatively, the distribution of the calculated investment opportunity scores can be shown on a tornado diagram (Figure 5.8). The tornado diagram shows that the variable that has the biggest influence on the value of the investment score is the risk associated with estimation of the resource, followed by net present value and marketability.

In this example, only one risk factor (partner risk) was treated as uncertain. That uncertainty is reflected in the preceding analysis. The @Risk software allows for as many factors as necessary to be treated as uncertain, and quantifies the cumulative effects of that uncertainty on the overall project risk.

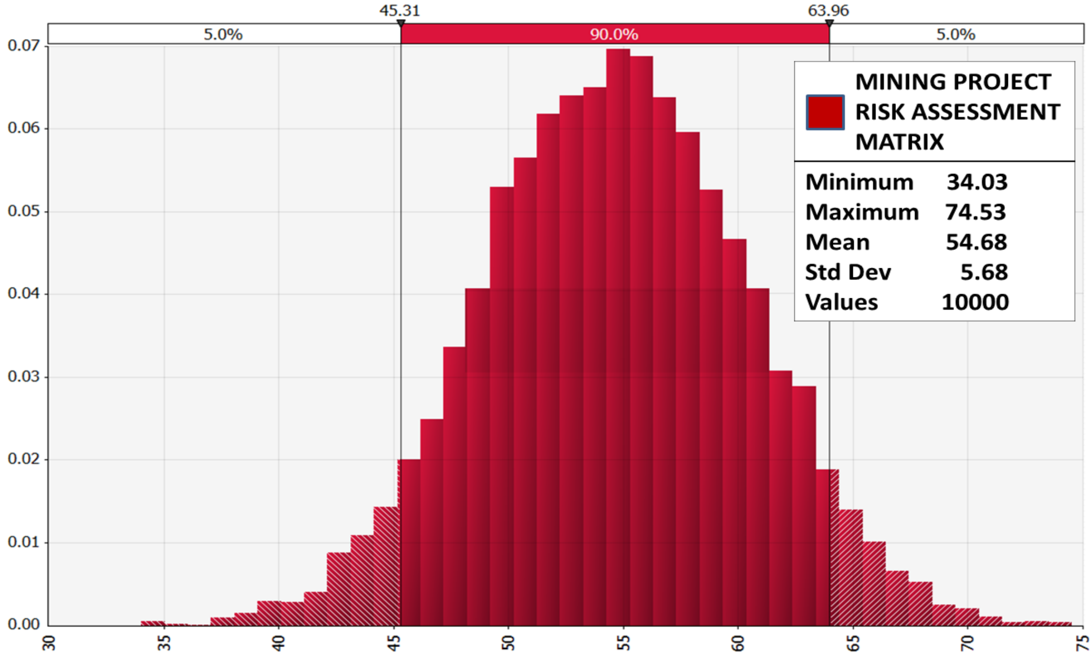


FIGURE 5.7 Output graph

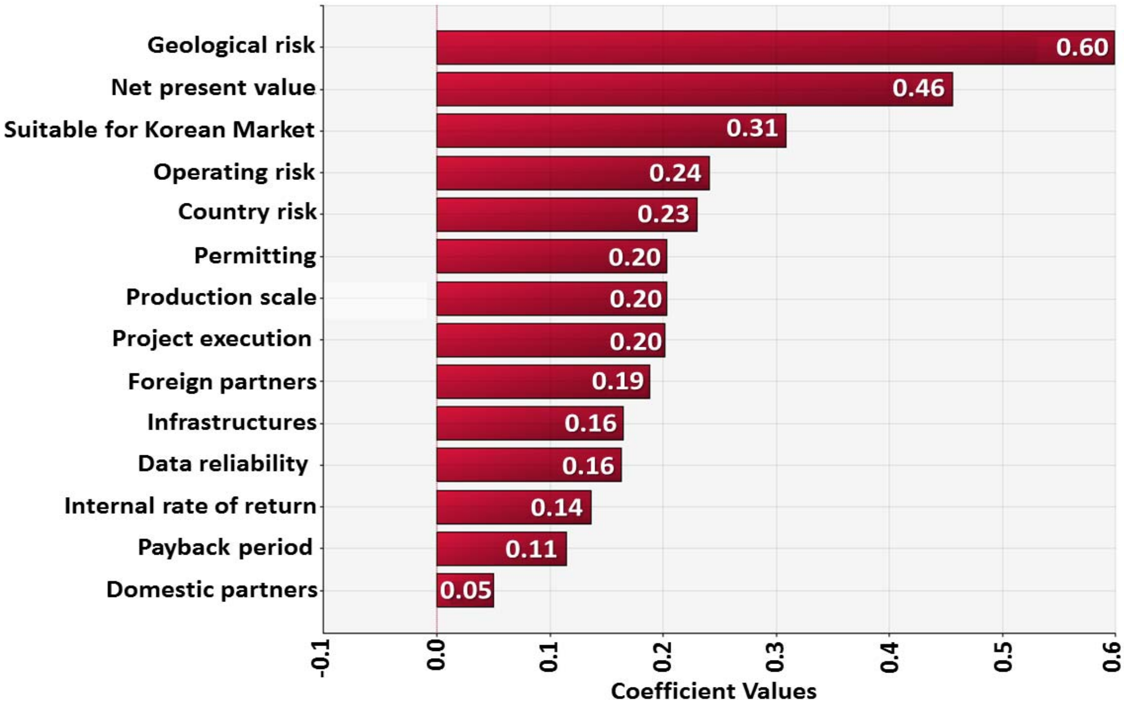
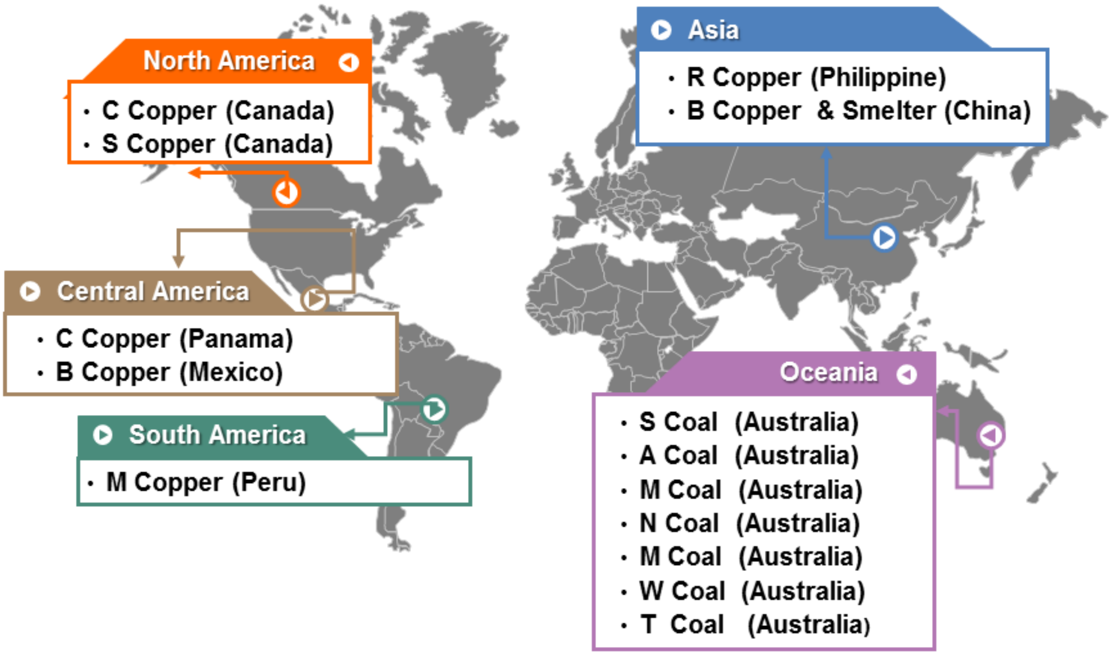


FIGURE 5.8 Tornado diagram

Several tests using hypothetical values confirmed that the logic and weightings of the risk assessment matrix shown in Table 5.7, and that investment risk analysis using the matrix and the @Risk software can be performed reliably and repeatedly.

5.2.2 Model Testing and Demonstration

This section describes testing and demonstration of the @Risk model using data from investment projects previously executed by K Company. To increase the validity of the tests, the author used 14 developing and operating projects in which K Company. invested during the exploration phase. Figure 5.9 shows the locations of those projects. At present, seven operating projects are providing good cash flow for K Company, and are a key part of its profitable operation. Seven developing projects have already overcome several risks and are expected to begin production within two years.



Source : K Company's internal information in possession of author

FIGURE 5.9 The location of K Company's developing and operating projects

Two sample projects, one producing coal mine and one developing copper project, will be discussed in detail to demonstrate how the matrix is used. The author was in charge of the coal project from 2007 to 2009, and examined the copper project in 2009.

Table 5.8 shows a general description of a coal project, summarized from K Company's analysis at the time the decision was made to participate in the project. The factors on which the risk analysis was based include the following: first, the project is located in New South Wales, Australia. K Company received an investment offer from a medium-sized Australian coal firm through its branch office in Sydney. K Company surveyed the proposed mine site twice. The second survey found that exploration was almost completed, and the operating company was preparing to do a feasibility study and prepare an environmental impact statement.

TABLE 5.8 Coal project description

Location	New South Wales, Australia
Ownership	Australian registered company has 100% equities
Commodity	High quality thermal coal for export market
Project Stage	Under feasibility study
Resources	325 million tons, reserves based on JORC
Proposed annual production	16 million tons of thermal coal
Infrastructures	Transportation, power, water, and port allocation are secured
Economic values	IRR 18.5%, positive NPV, 8 years payback

Source : K Company's internal information in possession of author

During these surveys, K Company also confirmed that coal quality at the site was suitable for the Korean market. There are several operating coal mines near this project so that there were no infrastructure risks. The operating company had contracts with a railway and the port authority, for transport and export of the coal produced, and had even made a coal supply agreement with local power plant. K Company made a decision to invest and submitted the proposal for consideration by domestic power generation companies, who were potential partners. Negotiations were difficult but eventually successful, and the deal was completed.

Table 5.9 shows K Company's evaluation of the risks associated with the investment, which was based on the company's internal documents, including reports for the board of directors and signed agreements.

TABLE 5.9 Coal project risk evaluation

Major (Proportion)	Minor (Weight)	Grades and comments		
Partner risk (8%)	Domestic partners (34.5%)	A	5 Korean Power Generation companies joined	34.5
	Foreign partners (65.5%)	A	Australian listed company is operator	65.5
Technical risks (43.2%)	Project Execution (17.3%)	C	Exploration works completed	4.325
	Geological risk (38.6%)	A	325 million tons of coal reserves basis	38.6
	Operating risk (20.7%)	A	Standard open cut mining and typical coal washing	20.7
	Production Scale (13.0%)	A	Annual 16 million tons of thermal coal	13.0
	Data Reliability (10.5%)	A	International standard (JORC) applied	10.5
Market-ability (8.6%)	Product standard (100%)	A	Suitable for South Korea, Trial shipping and test completed	100
Investment climates (18.2%)	Country risk (35.2%)	C	New South Wales is the lowest ranked in the mining world (Fraser Institute 2011)	0
	Permitting (31.1%)	C	Ready for Environmental Impact Assessment	0
	Infrastructure (33.6%)	A	Secured rail haulage, power and water supply	33.6
Economic values (22%)	IRR (23.0%)	B	Greater than 15%	11.5
	NPV (57.7%)	A	Positive NPV	57.7
	PBP (19.3%)	B	Less than 12 years	9.65

The following calculation explains how the project is evaluated.

Partner risk		8.0 % × (34.5+65.5)
Technical risks	+	43.2 % × (4.325+38.6+20.7+13.0+10.5)
Marketability	+	8.6 % × 100
Investment climates	+	18.2 % × (0+0+33.6)
Economic values	+	22.0 % × (11.5+57.7+9.65)
Total score	=	77.7

Table 5.10 shows a general description of the copper project, which is located in Panama. K Company received an investment offer from a Canadian copper mining firm, and then surveyed the proposed mine site and the Canadian company's branch office in Panama City. At that time, exploration was complete, and the operating company was planning to apply for an environmental impact statement and other required mining permits. Table 5.11 shows K Company's evaluation of the risks associated with the investment, which was again based on the company's internal documents.

TABLE 5.10 Copper project description

Location	Panama
Ownership	Canadian registered company has 100% equity
Commodity	Copper concentrates
Method	Open pit mining method
Project Stage	Feasibility study completed
Resources	1,642 million tons, resources based on NI 43-101
Proposed annual production	230,000 tons of copper concentrates
Infrastructures	Transportation and water supply are secured

Source : K Company's internal information in possession of author

TABLE 5.11 Copper project risk evaluation

Major (Proportion)	Minor (Weight)	Grades and comments		
Partner risk (8%)	Domestic partners (34.5%)	A	One of copper end-users joined	34.5
	Foreign partners (65.5%)	A	Canadian listed company as operator	65.5
Technical risks (43.2%)	Project Execution risk (17.3%)	B	Feasibility study completed	8.65
	Geological risk (38.6%)	A	1,642 million tons of resources basis (Measured and Indicated resources declared)	38.6
	Operating risk (20.7%)	A	Standard open pit mining and typical processing	20.7
	Production scale risk (13.0%)	A	Annual 200,000 tons of copper concentrates	13.0
	Data Reliability (10.5%)	A	International standard (NI 43-101) applied	10.5
Market-ability (8.6%)	Product standard (100%)	A	Suitable for South Korea and foreign market	100
Investment climates (18.2%)	Country risk (35.2%)	C	Panama is also ranked low in the mining world (Fraser Institute 2011)	0
	Permitting (31.1%)	C	Ready to apply for environmental impact statement	0
	Infra-structure (33.6%)	C	Transportation and water supply are secured	8.40
Economic values (22%)	IRR (23.0%)	B	Greater than 12%	11.50
	NPV (57.7%)	A	Positive NPV	57.7
	PBP (19.3%)	B	Less than 12 years	9.65

The following calculation explains how the project is evaluated.

Partner risk		8.0 % × (34.5+65.5)
Technical risks	+	43.2 % × (8.65+38.6+20.7+13.0+10.5)
Marketability	+	8.6 % × 100
Investment climates	+	18.2 % × (0+0+8.4)
Economic values	+	22.0 % × (11.5+57.7+9.65)
Total score	=	75.0

Twelve additional projects already executed by K Company were analyzed using the risk assessment matrix shown in Table 5.1. For these projects, the average ranking was 73 points, with range of 69 to 77. This indicates that the level of investment risk which K Company is willing to assume, assessed using the matrix in Table 5.1, is 73 points, at least for new project investments. When the same risk matrix was applied to one of K Company's missed investment opportunities, the risk rating came out 74 points. This indicates a different decision, which may have been better for the company, could have been made if this method had been used at that time.

Of course, the risk assessment matrix shown in Table 5.1 should be applied differently for each company, depending on the size of the organization, the magnitude of the mining projects where the company is involved, and the company's internal investment philosophy. Smaller companies may take on more risk because there may be fewer projects available to them, compared to international mining majors. Also major firms, like BHP Billiton, and Rio Tinto are more capable and willing than other mining companies to take risks. They may be marginally less risk averse than their medium sized competitors, depending on their assessment of the host country and other factors.

CHAPTER 6

CONCLUSIONS

In reality, the process of making mining investment decisions is as much idiosyncratic as it is scientific. This explains why there can never be any absolute or universal standards of adequacy for investment in the mining industry. It is always a question of what will satisfy a particular investor in a particular case and whether the project will satisfy the requirements of mining projects in general.

In considering overall project risk for an investor, it is important to recognize the objective of the investor in making the investment. In some cases this might be to generate a clear financial return. In other cases it might be to secure access to the resource for long term resource security. There may be several other reasons for investment. Risk must be considered against the investment objectives. Thus we need to recognize that if a major mineral deposit exists, even in a high risk country, investment may be made. Examples are Metallurgical Corporation of China's investment at the Anyak property in Afghanistan, Barrick's Reko Dig project in Pakistan, and investments by several companies in the eastern part of the Democratic Republic of the Congo (BD 2011).

The author has presented a risk assessment matrix used by K Company, a Korean company that invests in mineral projects. Based on a survey of 31 experts, that matrix was revised and improved. Using the revised matrix, investment risk scores for 14 projects in which K Company has already invested were calculated, and it was concluded that the logic and weightings of the matrix model are robust and accurately reflect the realities of the various elements that come into play in an investment analysis. The analysis shows that the most important areas relating to investment risk are:

1. The nature of the resources – resource, grade, access, and development potential
2. Economic values – positive net present value
3. Marketability – suitable for Korean market
4. Operating risk
5. Country risk and environmental constraints related to permitting

Although K Company is late coming into the market for mining properties, the author believes that it will be able to narrow its gap with larger mining companies by decreasing risks using results of this thesis. In addition, K Company typically investigates over 100 projects annually. By using this matrix model, the company will be able to complete those reviews more quickly and more effectively, making it possible to review more projects, or to review the same number of projects in greater details. This should lead K Company to make better investment decisions.

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